

# Testing ALPY 600 - Relative Flux Calibration using MILES Stars in Taurus 5-11-2016

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## Objective

To estimate the potential relative flux calibration accuracy and repeatability of spectra recorded and reduced at Three Hills Observatory using the ALPY 600 spectrograph by observing a number of stars from the MILES database.

## Equipment

Celestron C11 (280mm aperture), Meade focal reducer running at f5.2.

ALPY600 with guider and calibration modules.

ATIK 16IC-S guide camera. ATIK 428 science camera 2x binned (9.08um effective pixel size)

## Targets

Spectra of 7 bright MILES stars in Taurus were measured at similar elevation. All observations were made within a 1 hour period. No adjustments were made to the spectrograph or telescope. One of the stars (HD27819 A7v) was chosen as the reference for instrument response and atmospheric extinction correction and recorded near the beginning and again at the end of the run. Calibration exposures: bias(41x0.001s), dark(21x30s), flat(30x2s) and NeAr lamp (10x3s at start and end) were also taken using the ALPY Calibration Module.

ALPY 600		MILES test stars			05/11/2016		
Star	Vmag	spec type	Time	Alt	Az	exposure sec	notes
						10x	
HD26322	5.4	F2v	23:07	124	53	30	V IM Tau (delta Sct)
HD27819	4.8	A7v	23:17	130	44	30	64 Tau. Used as reference
HD28305	3.5	G9iii	23:31	132	47	3	eps Tau
HD27962	4.2	A2iv	23:35	135	47	10	V 776 Tau (alpha CVn)
HD29139	0.9	K5iii	23:40	134	45	0.5	Alpha Tau. Scintillation. Selected 10 from 20
HD27371	3.7	K0iii	23:45	141	46	5	gam Tau
HD30959	4.8	M3s	23:50	133	42	10	V omi 1 Ori
HD27819	4.8	A7v	23:58	143	49	20	Repeat reference

## Observations

PHD2 software was used for guiding. Each star was placed in the same position on the slit using the same xy coordinates for the guide position. The science camera was inadvertently run without cooling. The temperature varied from +1.3 to +1.8C. 10 exposures were recorded and combined for each star, targeting an SNR >200. The exposure time was chosen for each star to avoid saturation. (For HD29139 the required exposure time of 0.5 sec produced significant variation in intensity between exposures due to scintillation so 20 exposures were taken and the brightest 10 selected.)

## Reduction

The spectra were reduced using ISIS 5.7.0 software. There was no discernable shift between the two sets of lamp spectra so the mean was used to wavelength calibrate all spectra using the automatic line identification feature in ISIS. The calibration fit RMS error was 0.25A and the resolution R=490 as reported by ISIS. The first observation of HD27819 was used to calculate the instrument response and this was used to calibrate all the other observations in relative flux (normalised to 1 at 5500 Angstrom). A typical ISIS log file is attached as an Appendix.

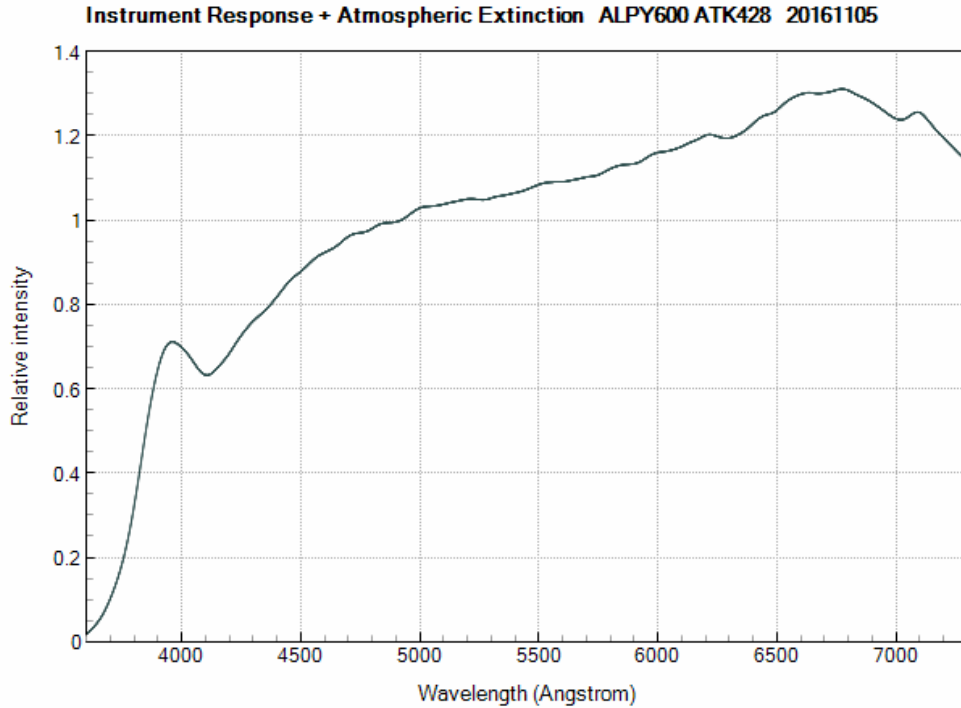
## Results

Graphs created using PlotSpectra by Tim Lester

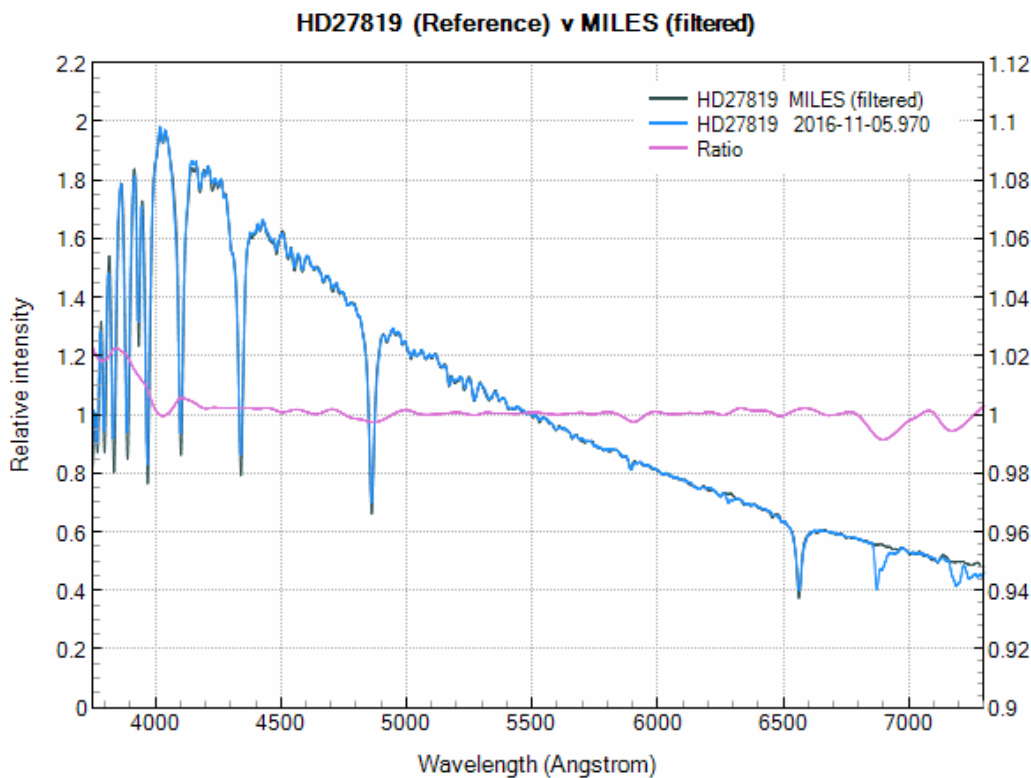
<http://www.spectro-aras.com/forum/viewtopic.php?f=8&t=1596>

The resulting spectra are shown in the following graphs in blue, overlaid on the corresponding spectrum from the MILES library of spectra (filtered to match the ALPY resolution) in black. By dividing the measured spectrum by the library version we can see more clearly the fractional error in the measured spectrum. This (filtered to remove localised differences) is also plotted, in pink

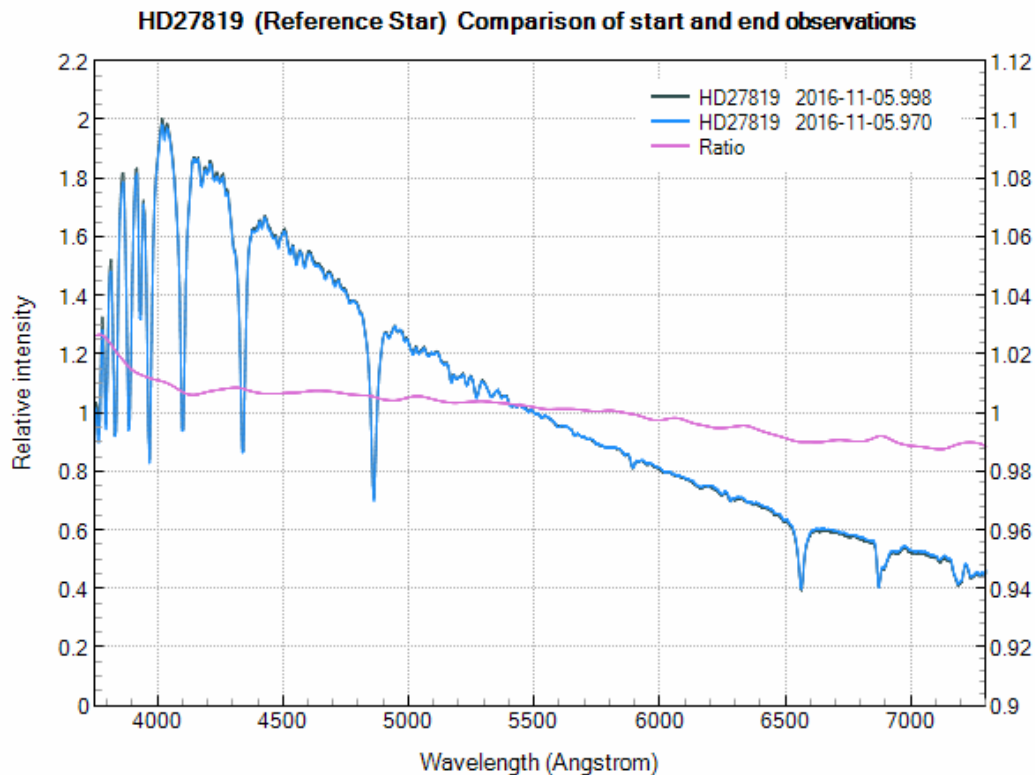
## HD27819 (reference star)



This graph shows the instrument response (including atmospheric extinction) calculated using the first observation of A7v star HD27819. (Note that ISIS assumes a black body curve for the flat lamp so the response is calculated relative to that).

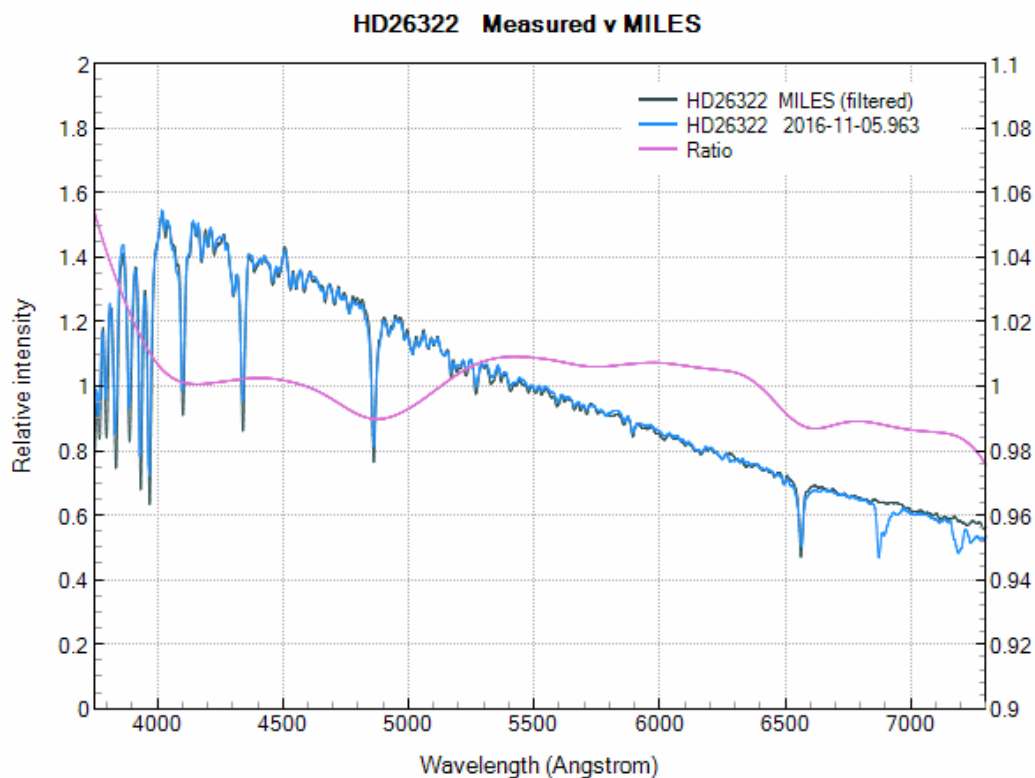


Unsurprisingly, since the instrument response is calculated based on these spectra, there is excellent agreement between the fully reduced observed and library spectra. The error is less than  $\pm 1\%$  4000-7300A. There is a small increase in the error below 4000A to 2%, most likely due to a small error in fitting the smoothed instrument response in this region where the response is low and falling steeply. (The additional absorption features in the measured spectrum around 7000A are telluric absorption bands).



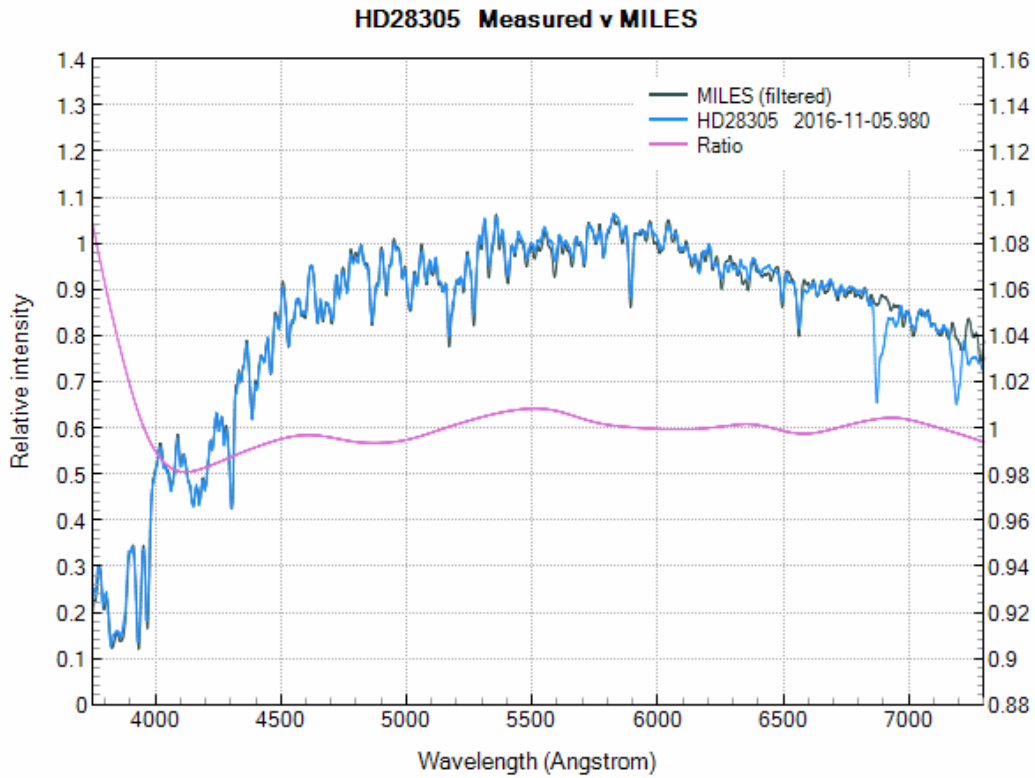
This graph compares the two spectra of HD27819 recorded 40 min apart near the start and end of the session. There is excellent agreement to within  $\pm 1\%$  4000-7300A rising slightly to 3% at 3750A. The small difference may be due to a reduction in atmospheric extinction as the star rose from 44 to 49 deg Altitude.

### HD26322



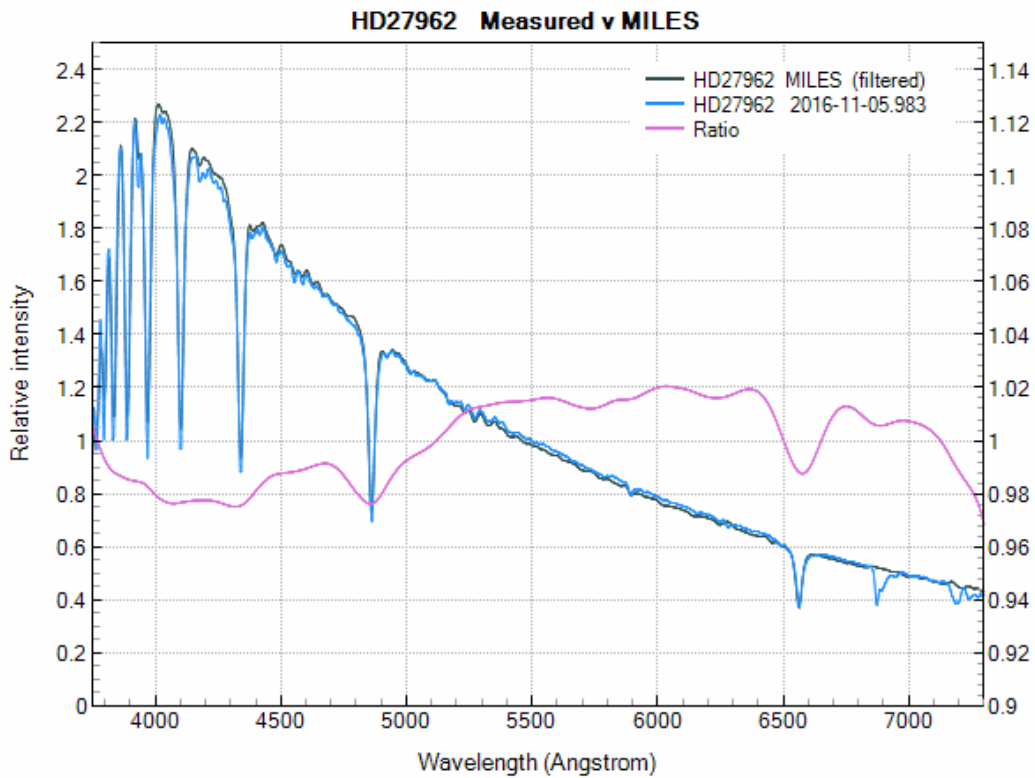
There is excellent agreement between observed and library with errors  $< \pm 2\%$  4000-7300A, rising to 5% at 3750A

## HD28305



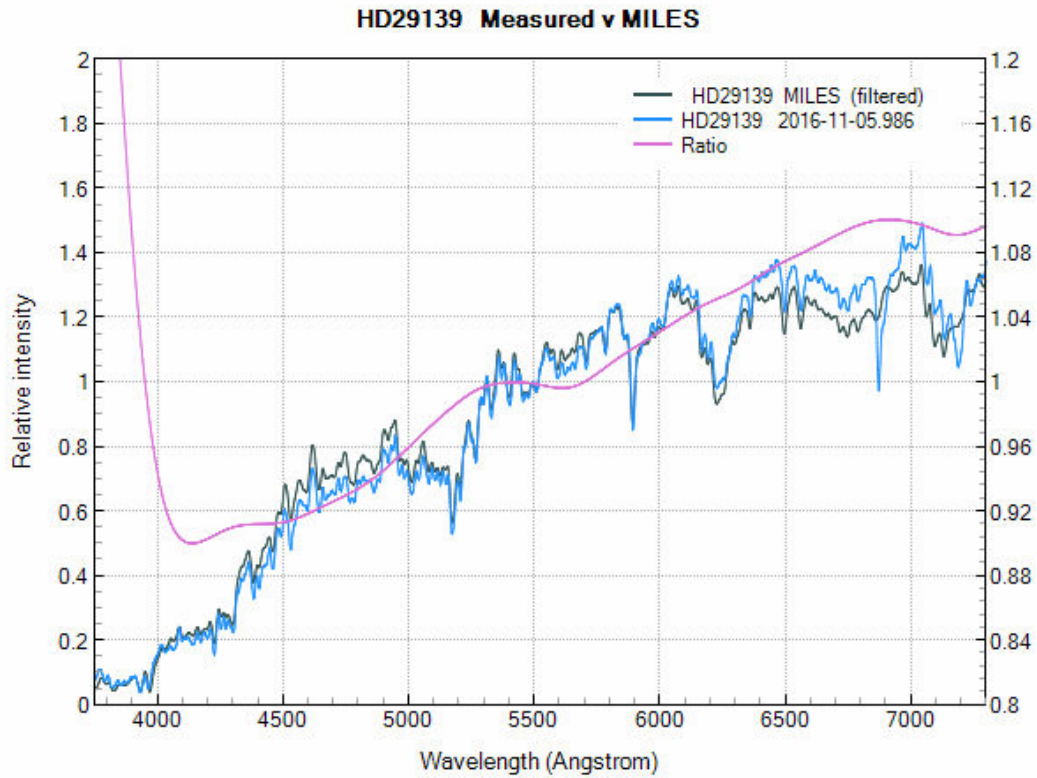
Again excellent agreement 4000-7300A at  $\leq \pm 2\%$  but the error rises steeply below 4000 to 8% at 3750A

## HD27962

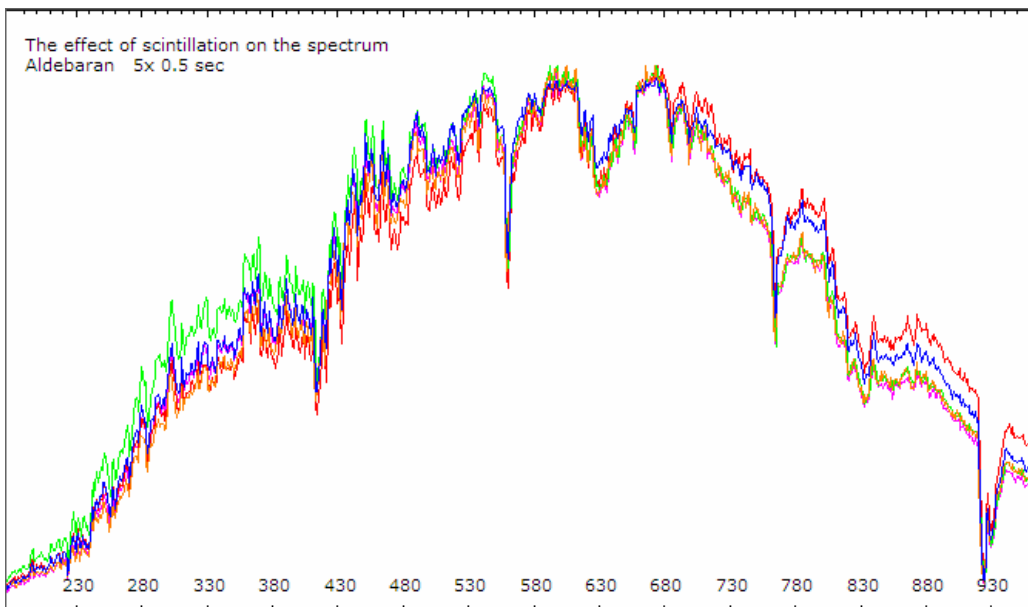


Excellent agreement within  $\pm 2\%$  across the full wavelength range 3750-7300A

# HD29139

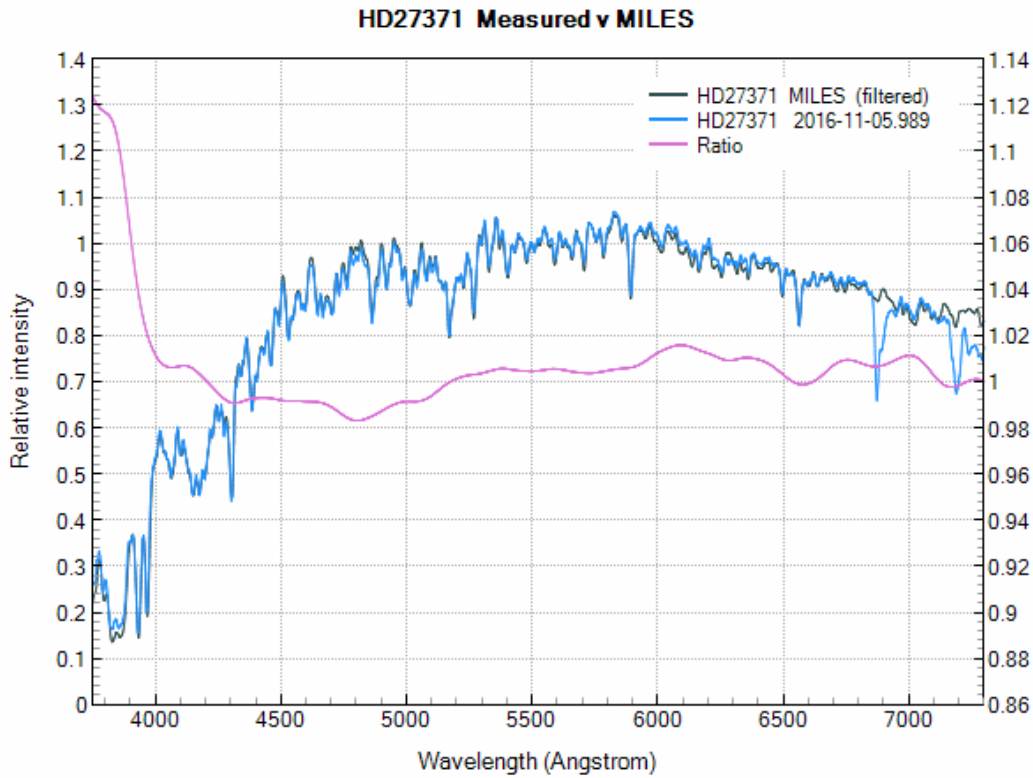


This star (Aldebaran) shows significant deviation (+-10%) from the library spectrum 4000-7300A rising rapidly to over 20% error by 3750A, though the flux from this cool star is very low in this region so the flux error in absolute terms is small. The relatively large errors here compared with the other stars may be due to scintillation which would not have averaged out in the short 10x 0.5 sec exposures.



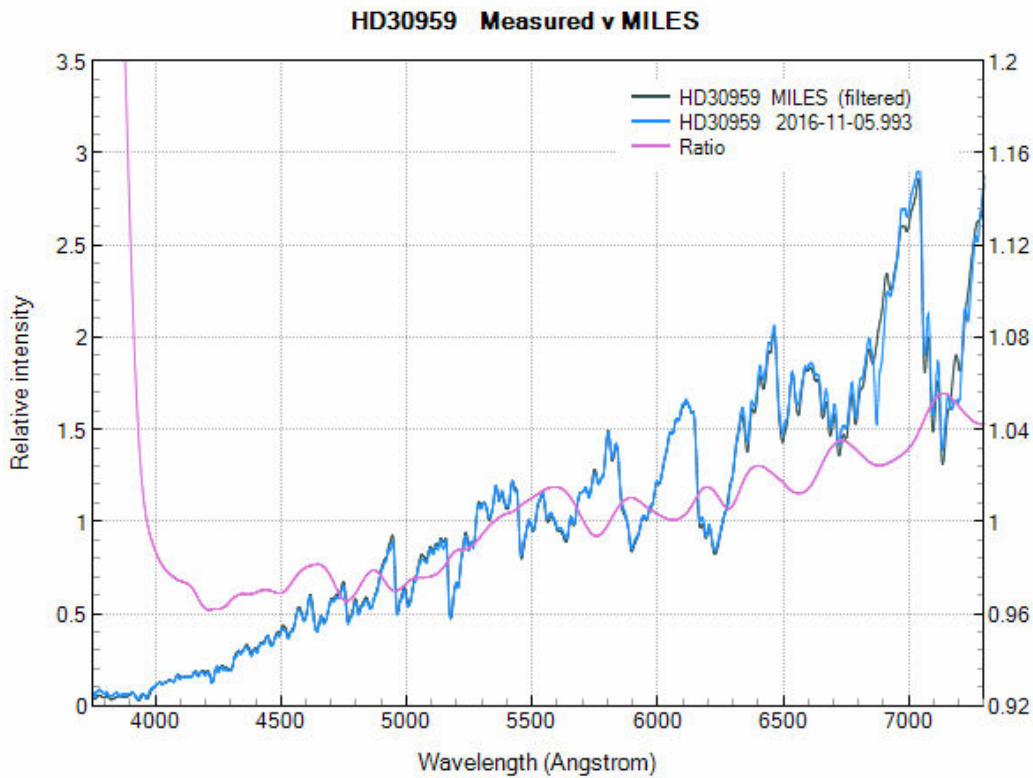
This graph shows the high degree of variability between individual 0.5 sec raw (uncalibrated) spectra due to scintillation.

## HD27371



Again good agreement within  $\pm 2\%$  from 4000-7300A but rising to 12% by 3750A

## HD30959



The errors are larger in this star at  $\pm 5\%$  4000-7300A rising to over 20% by 3750A. Again though this is in a region where the flux is low so the absolute error is small. This star is a cool S type star known to be variable so the difference between this observation and the spectrum in the library may be real.

## Discussion

Overall these results suggest that observations with the ALPY600 when used with the standard data reduction procedures used in ISIS is capable of producing excellent results in the range 4000-7300A with good repeatability and errors in relative flux of the order of 2% or better.

Scintillation is an issue with short exposures on bright targets but total exposures of greater than say 1 min should be sufficient averaging to give good accuracy.

All the results show a systematic deterioration in flux accuracy below 4000A. In every case the error is in the same direction relative to the reference star with the measured star reading high. The violet /UV is a tough region to get an accurate instrument response in as there are many potential sources of error in this region of the spectrum. The instrument response is low, the flat lamp output is weak and the atmospheric extinction and chromatic aberrations both in the telescope optics and the atmosphere are more pronounced. The good repeatability between the two reference star measurements near the start and end of the session suggests however that the errors are probably not due to changes between reference and target star measurement conditions. One clue is that the errors are inversely related to the flux level, so the percentage errors are greater for the cool stars where relative flux levels are lower in this region. This implies that the error may be due to a small flux offset. Further work is needed to investigate this.

## APPENDIX

### A typical ISIS log file

```
-----  
Version : ISIS V5.7.0  
Date du traitement : 06/11/2016 02:38:47  
-----  
Nom de l'objet traité : HD27962  
Nom complet du fichier de l'objet traité : _hd27962_20161105_983_Leadbeater.fit  
Chemin de sauvegarde : c:\users\user\desktop\20161105_alpy600_miles_tests\hd27962\  
-----  
Nom générique des spectres 2D bruts :  
c:\users\user\desktop\20161105_alpy600_miles_tests\hd27962\HD27962_  
Nombre de spectres bruts : 10  
Offset :  
c:\users\user\desktop\20161105_alpy600_miles_tests\hd27962\bias_ATK428_2xbin_1p5deg_201  
61105  
Dark :  
c:\users\user\desktop\20161105_alpy600_miles_tests\hd27962\thermal_ATK428_2xbin_1p5deg_2  
0161105  
Coefficient du dark : 0.3333  
Flat :  
c:\users\user\desktop\20161105_alpy600_miles_tests\hd27962\flat_ALPY600_ATK428_2xbin_1p  
5deg_20161105  
Etalonnage : mode standard  
Spectre lampe étalon :  
c:\users\user\desktop\20161105_alpy600_miles_tests\hd27962\lamp_ALPY600_ATK428_2xbin_  
29161105  
Position Y de référence : 402  
Taille pixel : 8.98
```

Registration verticale : non  
Soustraction du fond de ciel : oui  
Recentrage des spectres en longueur d'onde : non  
Angle de slant : 242  
Angle de tilt : -0.02  
Retrait des rayons cosmiques : non  
Limite X1 : 289  
Limite X2 : 675  
Fichier cosmétique :  
c:\users\user\desktop\20161105\_alpy600\_miles\_tests\hd27962\cosmetic\_ATK428\_2xbin\_1p5deg\_20161105  
Filtre gaussien : 0  
Fichier de réponse spectrale : \_hd27819\_20161105\_970\_response  
Fichier de transmission atmosphérique :  
Décalage spectral : 0  
Correction vitesse radiale : 0  
Facteur de binning en sortie : 1  
Indicatif du mode d'étalonnage : 30  
Longueur d'onde de référence : 5852.49  
Position X de référence : 552  
Instrument : C11\_f5\_ALPY600\_ATK428  
Résolution : 491  
Site : THO robin@threehillsobservatory.co.uk  
Observateur : Leadbeater  
Delta heure : 0  
Ciel Y1 : 50  
Ciel Y2 : 20  
Ciel Y3 : 20  
Ciel Y4 : 50  
Largeur de la zone de binning : 25  
Binning optimisé : non  
Zone de normalisation [ $\lambda$  1 -  $\lambda$  2] : [ 5450 - 5550 ]  
Somme standard des profils individuels  
Interpolation : bilinéaire  
A4 : 3.18856095420615E-10  
A3 : -1.09016727702811E-06  
A2 : 0.00083565045938299  
A1 : 4.7609761000238  
A0 : 3120.85294324042  
-----  
Date de prise de vue : 05/11/2016 23:34:51  
Durée de prise de vue : 113.0  
Durée de prise de vue décomposée : 10 x 10 s  
Date de milieu de prise de vue : 5.983/11/2016  
Jour Julien géocentrique du milieu de prise de vue : 2457698.4832  
Pouvoir de résolution : 490.6  
RMS de l'étalonnage spectral : 0.25370