Problems of the AMBER wavelength calibration

S. Štefl[1], A. Merand[1], J.-B. LeBouquin[2], F. Rantakyro[3], P. Bourget[1], A. Carciofi[4], T. Rivinius[1], D. Baade[5]

[1] *European Organisation for Astronomical Research in the Southern Hemisphere, Paranal and La Silla Observatories, Chile*
[2] *Lab. d'Astrophysique de l'Observatoire de Grenoble, France*
[3] *Gemini Observatory, Southern Operations Center, c/o AURA, Casilla 603, La Serena, Chile*
[4] *Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo, Rua do Matão 1226, São Paulo, SP 05508-900, Brazil*
[5] *European Organisation for Astronomical Research in the Southern Hemisphere, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany*

I. History of the AMBER dispersive unit status

- AMBER specification: non-repeatability in the dispersion unit (DIU) position up to 10 pixels, with a goal 1 pixel. No λ calibration assumed.
- Acreti 2003: DIU tests: accuracy within 1 pixel declared
- Grenoble 2003 - Paranal 2005: non-repeatability of a few tens of pixels. A software patch implemented to center the spectral window before performing the P2VM.
- Paranal 2006-7: accelerating degradation leading to a non-repeatability up to a few hundreds of pixels even for low motor speeds.
- September 2007: Emergency spectrograph intervention: non-repeatability improved to 20-30 pixels, when moving at 1000 steps/sec.
- January 2008: Large intervention - detailed analysis od the DIU mechanism, spectrograph twice warmed and opened, main results:
  — A new worm with its bearings installed. It allows to adjust the worm-wheel backlash (see Fig. 1)
  — Dispersion unit motor replaced
  — Intensive DIU tests performed

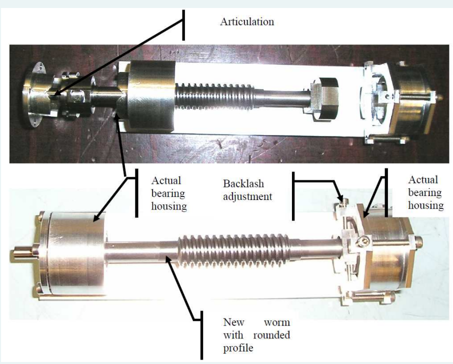

Fig. 1: Critical DIU part, which was replaced during the 2008 intervention.

Tests summary and recommendations

- ⋆ Temperatures of the controller board and of the motor are critical DIU parameters. The DIU should be operated at fixed board and motor temperatures.
- ⋆ DIU should be systematically inicialized and then moved directly to the setting position (without moving to zero order position).
- ⋆ The mechanism itself produces an uncertainty in the DUI positioning of the order of several pixels

II. How accurate is our AMBER wavelengths calibration now?

a) Stabily on a time scale of several months:

— Observing campaign on the Be star 28 (ω) CMa in November 2008 - May 2009 (ESO program 282.D-5014), 16 AMBER observations in the HR mode (R=1500), Brγ region, spectra extracted

— Quasi-simultaneous HR (R $\sim$ 45 000) Phoenix/GEMINI spectra

— Cross-correlation of the AMBER and Phoenix Brγ profiles.

— For illustration, we show results for each date and baseline.

Julian date	Baseline	wavelength offset [x 10^{-3} μm]
54782.28	G1-A0	-1.541
	K0-A0	-1.548
	K0-G1	-1.562
54782.32	G1-A0	-1.562
	K0-A0	-1.546
	K0-G1	-1.555
54819.33	G1-A0	-1.602
	K0-A0	-1.603
	K0-G1	-1.611
54826.27	G1-A0	-1.584
	K0-A0	-1.591
	K0-G1	-1.593
54833.33	G1-A0	-1.545
	K0-A0	-1.554
	K0-G1	-1.556
54826.37	G1-A0	-1.545
	K0-A0	-1.554
	K0-G1	-1.556
54879.21	D0-H0	-1.519
	G1-D0	-1.547
	G1-G1	-1.546
54881.16	D0-H0	-1.555
	G1-D0	-1.573
	G1-G1	-1.547
54908.06	D0-H0	-1.536
	G1-D0	-1.578
	G1-G1	-1.546
54911.10	G1-A0	-1.553
	K0-A0	-1.522
	K0-G1	-1.543
54912.08	G1-A0	-1.574
	K0-A0	-1.576
	K0-G1	-1.611
54912.12	G1-A0	-1.550
	K0-A0	-1.550
	K0-G1	-1.590
54913.13	G1-A0	-1.539
	K0-A0	-1.517
	K0-G1	-1.572
54932.02	G1-A0	-1.534
	K0-A0	-1.518
	K0-G1	-1.556
54952.98	D0-H0	-1.595
	G1-D0	-1.608
	G1-G1	-1.571
54954.00	D0-H0	-1.558
	G1-D0	-1.574
	G1-G1	-1.546

b) Short-term stability

— Test with the ThAr lamp, high resolution, central wavelength 2.056 μm

— ThAr spectra exposed before and after the calibrator

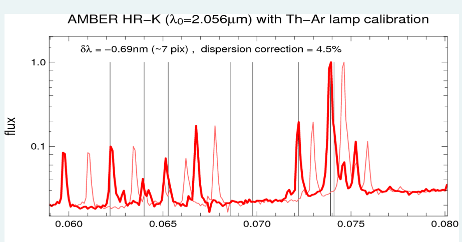

Fig. 2: Th Ar spectrum exposed before and after the calibration.

Summary

- ⋆ Wavelength offset is always negative (consistent with the known problem of lost steps during the DIU movement) and relatively stable on a long timescale. The mean offset derived from our limited sample for the high resolution mode and Brγ region (High_K_1_2.172 setting) and all used baselines is (-1.561 $\pm$ 0.024) x 10^{-3} μ ($\sim$16 pixels)
- ⋆ Drifts by a few pixels can appear even at th short timescale of the order of a calibration sequence

III. Can the calibration quality impact the science results

Example: HR mode, observations of circumstellar disks of Be stars in emission (mostly Brγ) lines:

— When fitting the visibility profiles, the wavelength offset must enter the fitting procedure as a free parameter

— Symmetric visibility profile (e.g. 28 CMa during our 2008/9 campaign) - the wavelengths offset is fitted unambiguously and does not affect significantly the fitting of physical disk parameters

— Asymmetric visibility profiles corresponding to a photocenter shift (e.g. ζ Tau) - The fitting procedure looks for a compromise between the wavelength offset and asymmetry of the visibility profile.

- ⋆ The unreliable AMBER wavelengths calibration can negatively influence the interpretation of science data

IV. Solutions being considered

— Measurements of the gratting position using a laser beam through the spot where one mounts the black body light and a software correction of the wavelength calibration. Proposed by F. Rantakyro, not further developed.

— Telluric lines: Wavelength calibration in some HR and MR settings can be performed with telluric lines except the the low-resolution mode. No telluric lines in some HR windows.

— ThAr lamp: First tests done in November 2009-January 2010.

V. Conclusions

- ⋆ Even after recommended hardware and software modifications, the DIU positioning is not within specifications.
- ⋆ The present -as well as close to the specification- accuracy of the DIU positioning implies undifined wavelengths offsets, which can impact the scientific interpretation of the data.
- ⋆ A goal of 1 pixel accuracy would very probably need a new mechanism design
- ⋆ Unlike the original concept, we recommend a standard spectroscopic wavelength calibration using calibration lamps or telluric spectra. Testing and optimization of both methods is in progress.