Master response curves for flux calibration of VIMOS spectroscopy

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1 VIMOS spectroscopic modes

The VIMOS instrument[1] at the Nasmyth B focus of the VLT-Melipal telescope has four identical optical arms (quadrants); each is equipped with 6 different grisms of spectral resolution between 200 and 2500 (for 1″ slits). Two spectroscopic modes are offered: Multi Object Spectroscopy (MOS) using masks with up to 200 slits per quadrant and Integral Field Unit (IFU) spectroscopy with 6400 fibres (80x80).

Spectro-photometric standard stars are measured on a regular basis in both spectroscopic modes. They are usually observed near in time to science observations with the same grism setting. Standard star observations are used for monitoring of the spectral instrument efficiency and are also intended for providing response curves for flux calibration of scientific data. Limitations for the usage of response curves arise since standards are not always observed under optimum weather conditions (and not in the same conditions as the science data) and telescope scheduling requirements may prevent timely observation of standards.

2 Master response curves

The dependency on individual standard star measurements can be relaxed by using averages of response curves from a dedicated time interval for relative flux calibration. These averages are called master response curves.

Individual response curves $R(\lambda)$ have been derived with recipes of the VIMOS pipeline:

$$R(\lambda) = F_{\mathrm{std}}(\lambda)/f_{\mathrm{std}}(\lambda) \tag{1}$$

where $F_{\mathrm{std}}(\lambda)$ is the tabulated standard star flux in erg cm^{-2} s^{-1} Å^{-1} and $f_{\mathrm{std}}(\lambda)$ is the observed flux corrected for airmass and extinction, i.e.

$$f_{\mathrm{std}}(\lambda) = f_{\mathrm{ins}}(\lambda) 10^{0.4\mu \Delta m(\lambda)} \tag{2}$$

with $f_{\mathrm{ins}}(\lambda)$ in e^- s^{-1} Å^{-1}, extinction $\Delta m(\lambda)$ in magnitudes and airmass μ.

Master response curves have to be created for each spectroscopic setting in MOS and IFU for each quadrant separately. Individual response curves measured during a dedicated period have been inspected, clearly deviating curves have been de-selected, and the remaining ones have been averaged to create a final master $R_{\mathrm{mst}}(\lambda)$ for this setting and quadrant.

3 Verification

The resulting master response curves have been verified by selecting a random set of standard star observations, applying the response $R_{\mathrm{mst}}(\lambda)$ to the extracted spectrum $f_{\mathrm{ins}}(\lambda)$

$$F_{\mathrm{obs}} = R_{\mathrm{mst}}(\lambda) f_{\mathrm{ins}}(\lambda) 10^{0.4\mu \Delta m(\lambda)} \ , \qquad (3)$$

and comparison to the tabulated flux. The typical accuracy is 10% for relative flux calibration within an individual spectrum.

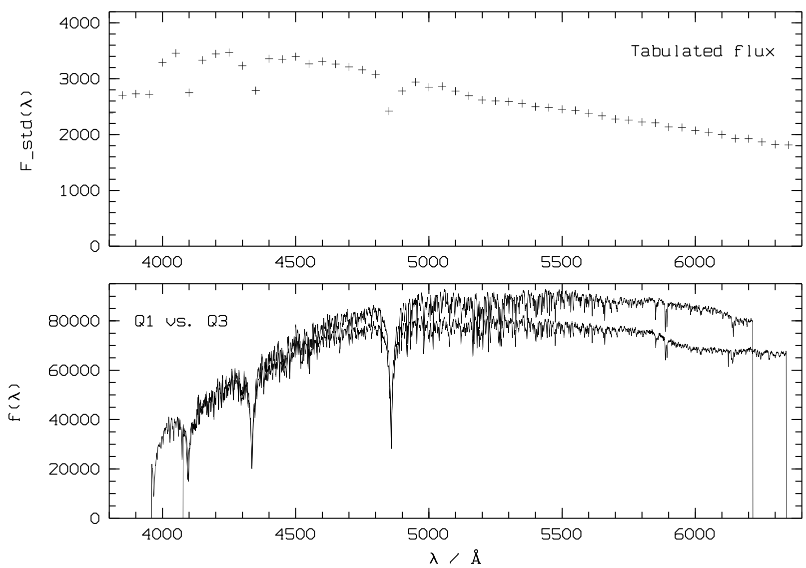

Fig. 1. Tabulated flux (in 10^{-16} erg cm^{-2} s^{-1} Å^{-1}) of the standard star CD −32°9927 (top) and pipeline-extracted spectra without flux calibration of a MOS observation with HR_blue grism from 31 March 2006 (bottom)

Fig. 1 shows an example for MOS. The top panel illustrates the tabulated flux for the standard star CD −32°9927. The lower panel shows the pipeline-extracted flux from an observation on 31 March 2006 with the HR_blue grism. A flux calibration has not yet been applied. The extracted spectra in quadrants 1 and 3 differ significantly over a major part of the wavelength range.

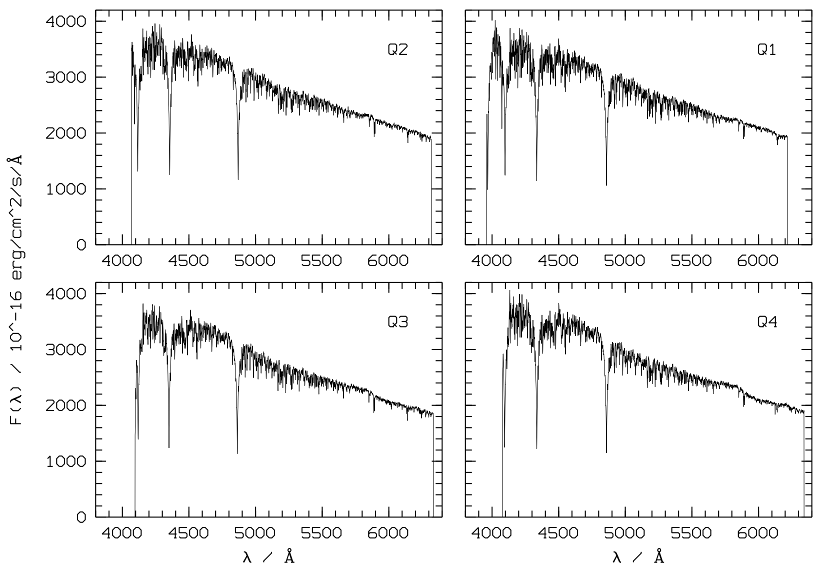

Fig. 2. Flux-calibrated observation of CD $-32°9927$: master response curves have been applied in all four quadrants

Fig. 2 shows the same observation with master response curves for MOS HR_blue applied. All four quadrants have now similar flux and spectral shape. The difference between quadrants 1 and 3 has disappeared.

Finally, Fig. 3 shows the residuals of the flux calibration: flux-calibrated spectra divided by tabulated flux. The deviations are within 10% of the actual flux. Some differences in the Balmer lines occur because of different sampling of the tabulated flux and the observation.

IFU flux-calibrated spectra have also been verified. Here, the pipeline product is a 3D data cube with spatial and spectral information. The flux calibration is applied per fibre. The 2D image of a standard star is usually much larger than the spatial resolution of each fibre. For a comparison with the tabulated flux, the spectra from all fibres in a quadrant have been added. The background has been estimated from fibres without signal and subtracted. The results show an agreement similar to the MOS case.

4 Limitations and availability

Master response curves have been created with data from September 2005 to November 2006. The number of available observations and therefore the accuracy of the masters depend on the setting. Some general intrumental and observing limitations also have an influence. For MOS, slit losses can occur

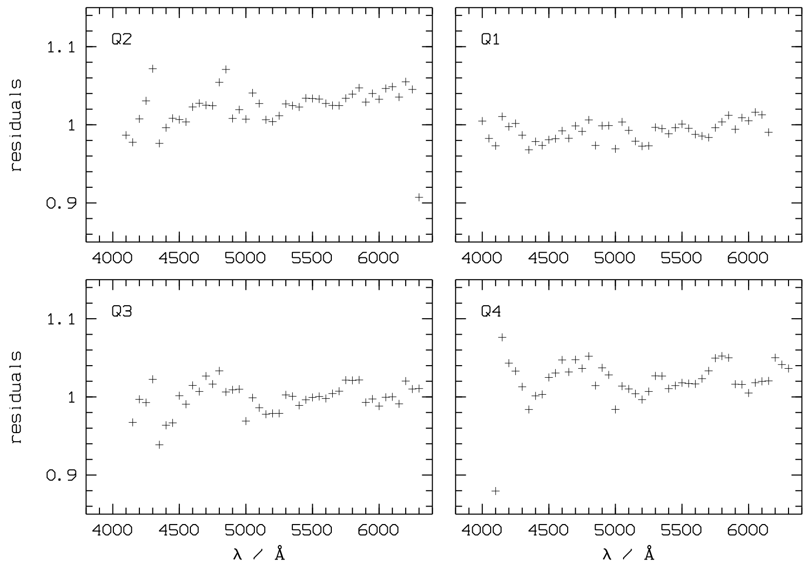

Fig. 3. Residuals: flux-calibrated spectra of CD −32°9927 divided by tabulated flux

and are dependent on wavelength because of atmospheric dispersion. In case of IFU, the spectral response varies over the field for each quadrant (see talk by M. Roth). This is not completely corrected by throughput correction from flat fields.

Changes of the global efficiency with time cannot be accounted for with this method. Applying the curve to an arbitrary observation will result in a small offset with respect to the absolute flux. However, regular standard star measurements show that the relative response within each setting is in general stable.

Master response curves have been created for almost all VIMOS spectroscopic settings. They can be downloaded from:
www.eso.org/qc/VIMOS/qc/response.html. They will be used for pipeline reduction of VIMOS Service Mode data.

References

1. O. LeFevre, M. Saisse, D. Mancini et al: Commisioning and performances of the VLT-VIMOS instrument. In: *Instrument Design and Performance of Optical/Infrared Ground-based Telescopes*, ed by M. Iye, A. Moorwood (Proc. SPIE, vol 4841, 2003) pp 1670–1681