Notes on Flux Calibration of ESPaDOnS data with OPERA

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CFHT, Feb 2013

There are basically three different ways to perform flux calibration of ESPaDOnS data using OPERA:

a. Using calibrators observed on the same night

This method uses only data from a calibrator, which is typically an A-type standard star, observed at the same night as the target and with the same observing MODE and DETECTOR. This type of calibration assumes that sky conditions were photometric and the standard star(s) and the target have been observed under similar conditions such as seeing, airmass, time, etc.

b. Using ./config/*.fcal master calibration

This method uses a master calibration file, which has been produced using calibration data from standard stars observed along the course of many nights. All the calibration data used to produce the master file must have been observed under photometric sky conditions.

c. Using a constant

In fact this method doesn't calibrate the data. It only applies a constant scale factor, in case the user wants to rescale the data. The constant should be set to unit (`--inputconstant=1`) to keep the data intact.

There are three OPERA modules involved in the flux calibration:

I. **operaCreateFluxCalibration**

This module creates an OPERA Flux Calibration file (*.fcal) out of a single observation of a standard star. The module requires the following inputs:

- uncalibrated OPERA spectrum (*.e) of a standard star
- calibrated low-resolution template spectrum of the same standard star
- OPERA wavelength calibration file (*.wcal)
- OPERA aperture calibration file (*.aper)
- exposure time for the uncalibrated spectrum

The output calibration file contains the spectral dependency of the conversion factor between the measured flux and the flux in the same units as the input template per unit of time (s). It is also possible to set the option `normalizeCalibratedSpectrum=1`, which will normalize the template, i.e. the normalization will be chosen such as the maximum flux value is 1.

II. **operaMasterFluxCalibration**

This module creates an OPERA flux calibration (*.fcal) out of multiple calibration files (*.fcal). The input calibration files don't necessarily need to contain the same sampling or same number of points. The output file will be resampled (by spline interpolation) to the same grid as in the input reference spectrum (`--inputReferenceSpectrum=*.e`). This module runs every night to combine all calibrations available and create a master calibration file for that night, where many observations of standard stars may be available. However the same module can also be used to produce a master calibration file for an entire run or for all the lifetime of the instrument. The method to combine data points from multiple calibrations can be selected under the input `--combineMethod=1`, however the only method available currently is #1=mean, which calculates the arithmetic mean.

III. **operaApplyFluxCalibration**

This module takes an OPERA flux calibration file (*.fcal) as input and applies the calibration to a given uncalibrated spectrum (*.e). The output has the same format as the input spectrum. The module also requires the exposure time as input.
In fact this module is not part of the core reduction of OPERA, since the flux calibration is done together with other processes in the modules that produce the final OPERA products (*.m). However, all the processing is done by the libraries which are called from the modules, therefore the results produced by this module should be identical to those given in the OPERA products.