Molecfit: A Package for Telluric Absorption Correction

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Introduction

Ground based astronomical spectra are affected by molecular absorption from the Earth's atmosphere. This absorption is usually corrected with the help of telluric standard stars, which have to be observed with the same airmass and spectral mode directly before/after the science target to obtain calibration frames taken under the same atmospheric conditions. This approach is very cumbersome and expensive in terms of telescope time. We have developed the software package `molecfit`[1], [2] which aims at creating synthetic transmission curves which can be used for the telluric absorption correction.

Method

The code package `molecfit` performs the telluric absorption feature correction in two steps: (a) A synthetic spectrum is created on basis of an atmospheric molecular abundance profile[a,b,c], containing meteorological information at the time of the science observations, the spectral line database HITRAN[d] [3], and the radiative transfer code LBLRTM[e] [4]. The continuum, the wavelength correction, the Line Spread Function, and the molecular abundance profile are iteratively varied and used for creating synthetic spectra. By incorporating a Levenberg-Marquardt χ^2 minimisation algorithm (CMPFIT[f] package) a best fit is achieved between the synthetic and the telluric features visible in the input spectrum (see Figure 1). (b) The resulting transmission spectrum is then used for the telluric absorption feature correction.

Results

We have successfully applied our method to various instruments. Figure 2 shows a near-IR arm spectrum of the galaxy NGC-5638 taken with the X-Shooter spectrograph mounted at the ESO VLT[g]. We used `molecfit` directly on the science frames without incorporating the corresponding telluric standard star observation. The two regions (I) and (II) show the quality of the corrections with low and high atmospheric absorption in detail.

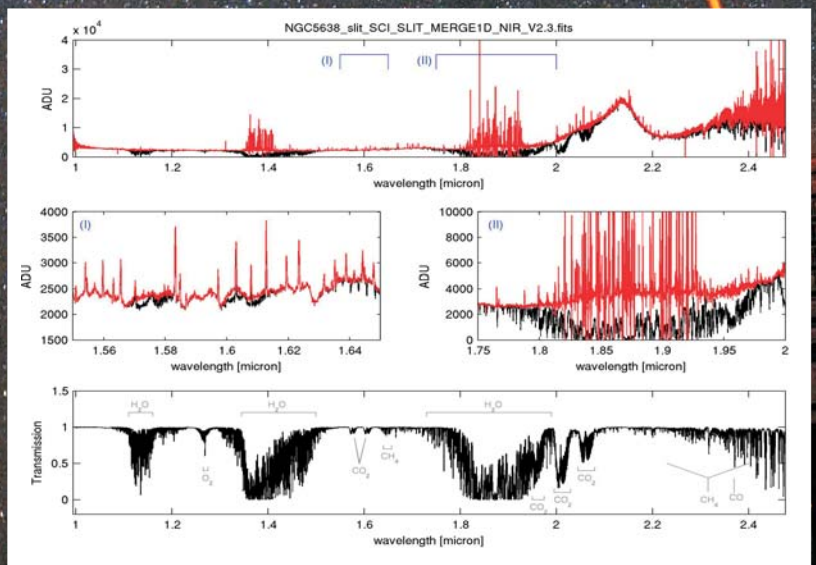

Figure 2: X-Shooter@ESO VLT example of the telluric absorption feature correction performed by `molecfit`. The uppermost panel shows the original NIR arm spectrum of the galaxy NGC-5368 (black lines) and the corrected one (red lines). Regions (I) and (II) show the quality of the telluric feature correction in case of low and high absorption, respectively (middle panels). The lowest panel shows the transmission curve calculated by `molecfit` including an identification of the most prominent molecular features. In the entire wavelength range, a good correction of the telluric absorption features is achieved.

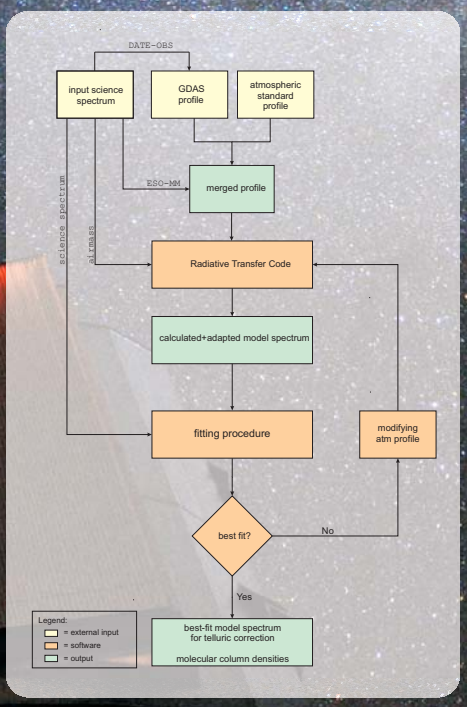

Figure 1: Principle workflow of the fitting procedure ([2]): Based on the observing date, an appropriate atmospheric profile is created and used as input for the radiative transfer code LNFL/LBLRTM to calculate and iteratively fit a transmission spectrum for the telluric absorption correction. The best fit can also be used to determine molecular column densities.

Acknowledgements: This study is carried out in the framework of the Austrian ESO In-Kind project funded by the Austrian Ministry for Research (BM:wf) under contracts BMWF-10.490/0009-II/10/2009 and BMWF-10.490/0008-II/3/2011. This study is also supported by the Austrian Science Fund (FWF), project P26130.

References:

[1] Smette et al., 2009, IAU XXVII General Assembly, ESO Chile
[2] Molecfit User Manual VLT-MAN-ESO-19550-5772 + references therein
[3] Rothman et al. 2009, JQSRT 110, 533
[4] Clough et al. 2005, JQSRT 91, 233

Links:

[a] `http://www.atm.ox.ac.uk/RFM/atm/`
[b] Global Data Assimilation System: `http://ready.arl.noaa.gov/gdas1.php`
[c] ESO MeteoMonitor `http://archive.eso.org/asm/ambient-server?site=paranal`
[d] High-resolution transmission molecular absorption database: `http://www.cfa.harvard.edu/HITRAN/`
[e] Line-By-Line Radiation Transfer Model: `http://rtweb.aer.com/lblrtm_frame.html`
[f] CMPFIT: `http://www.physics.wisc.edu/~craigm/idl/cmpfit.html`
[g] ESO: `http://www.eso.org`