Synthetic Telluric Spectra

The near-infrared spectrum of the Earth's atmosphere contains a large number of absorption features due mainly to vibration-rotation bands of H_2O, CO_2, CH_4, N_2O, and O_3. Classically these features have been removed from program star spectra by ratioing the program spectrum to that of a 'telluric reference' star, typically a hot star. This approach presents several problems. The presence of occasional features from the hot star, e.g. a hydrogen line, must be separately synthesized and removed. A more pressing problem is the quality of the ratio. Many of us were originally content with a single hot star observation each night. This spectrum was then adjusted using Beer's Law. Better spectrographs resulted in more frequent observations of telluric standards. A substantial observing time overhead can be accrued in observing telluric standards. A telluric reference spectrum must exceed the S/N of the program spectrum. Furthermore all the species in the Earth's atmosphere are not well mixed. There is a dense and highly variable H_2O ground layer (see for instance Seifahrt et al. 2010 Figure 1). So even carefully observed telluric reference spectra may not result in perfect fits to the program star telluric spectra.

It is now possible to synthesize telluric spectra that are excellent matches to observed telluric spectra. Several routines are available to compute the radiative transfer. All rely on the HITRAN molecular database (https://www.cfa.harvard.edu/hitran/). An input model atmosphere giving vertical temperature, pressure, and molecular abundance profiles is also required.

A review of radiative transfer codes and atmospheric models that were available in 2010 can be found in Seifahrt et al. (2010). Seifahrt et al. recommend the LBLRTM (http://rtweb.aer.com/lblrtm_description.html) package that is available as freeware. Seifahrt et al. also reviews model telluric atmospheres and provides links.

Molecfit, a tool to correct for telluric absorption lines through spectral synthesis, was written for ESO instruments and is presented by Smette et al. (2015). This package and related material can be found at
http://www.eso.org/sci/software/pipelines/skytools/

ATRAN, a less sophisticated but very easy to use routine was developed in the 1990s (Lord 1992) and is available on the SOFIA web site. The link is
https://atran.sofia.usra.edu/cgi-bin/atran/atran.cgi

One caveat is that the telluric models do not include airglow lines. However, these lines should not appear in reduced spectra. If you nodded along the slit or nodded to sky the differencing of the images should cancel these lines. We strongly advised all near-infrared observations be nodded.

References

Lord, S.D. 1992, NASA Technical Memorandum 103957

Seifahrt, A., Käufl, H.U., Zängl, G., et al. 2010, A&A, 524, A11

Smette, A., Sana, H., Noll, S., et al. 2015, A&A, 576, A77