An advanced UV to IR Sky Background Model for ESO Sites

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Innsbruck in-kind Project: S. Kimeswenger☺, S. Noll, W. Kausch, M. Barden, A.M. Jones, C. Szyszka

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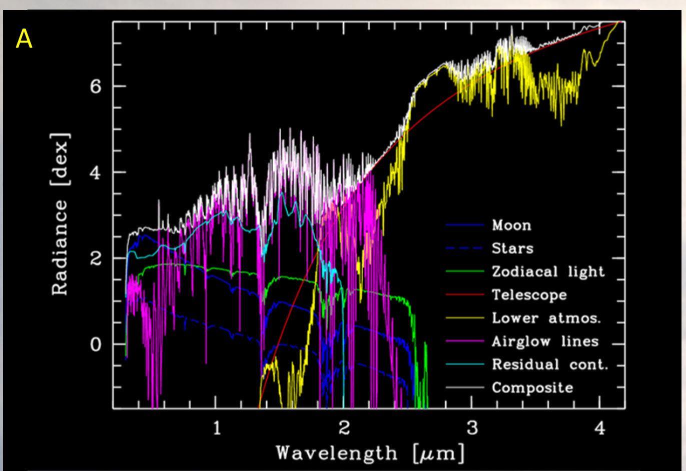
Image: ESO/Y. Beletsky

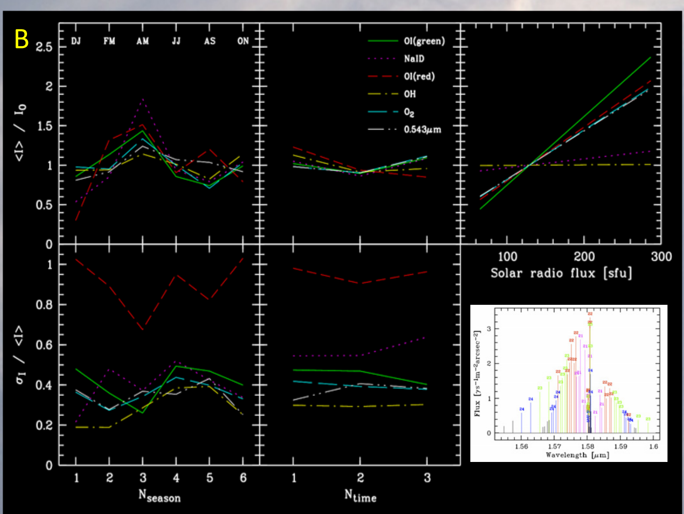
Introduction:

The quality of ground-based observations is strongly affected by scattering, absorption, and radiation processes in the Earth's atmosphere. For instrument design, future exposure time calculators (ETCs), and effective telescope time management, it is important to accurately estimate the wavelength dependent contribution of the Earth's atmosphere to the observed flux. We are also working on a first step towards a model-based data reduction/calibration. For this reason, we developed an atmospheric radiation model containing seven individual components (Fig. A) for the VLT and E-ELT sites.

These theoretical models were compared and calibrated using more than a thousand night sky spectra obtained at the VLT by various instruments. This allows us to give reliable estimates for the range of parameters as a function of weather conditions, solar activity cycle, night time, Moon phase, ...
Further on, it allows us to derive estimates for systematic errors in 'classical' data reduction (e.g. shift of effective wavelength in IR broad band photometry – Fig. D) and to correct/improve wavelength calibrations and thus improve the sky subtraction (Fig. F). For the latter purpose the models were used to improve the method for OH lines by Davies (2007, MNRAS, 375).



(A) The components of the model for a night during grey time.



(B) Variability correction for the five airglow line classes green OI, NaID, red OI, OH, and O_2, and the airglow continuum (analysed at 543 nm). *Upper panels*: The variability depends on bi-monthly period (1 = Dec/Jan,..., 6 = Oct/Nov), time bin (third of the night), and solar activity measured by the solar radio flux. *Lower panels*: For the bi-monthly period and time, the relative uncertainties of the variability correction are shown as well. The insert shows some groups of OH lines coupled by their physics. Thus the ‚calibration' by a few bright lines of a group give reliable estimates for (blended) faint features.

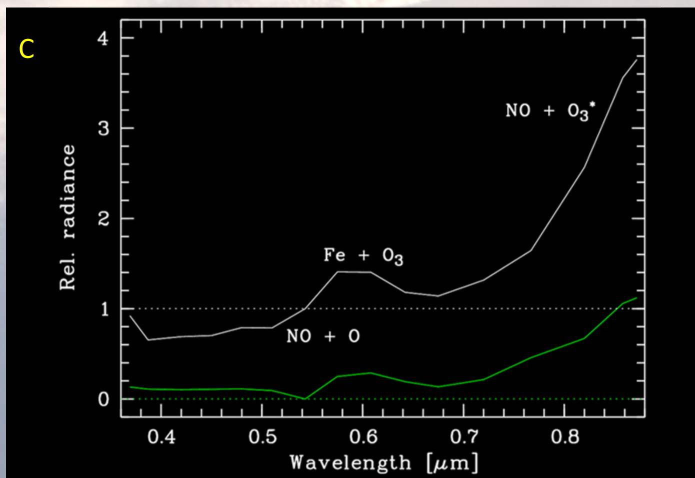
The Project:

The project was initiated by the in-kind contributions of Austria's ascension to ESO. It originally aimed at building an improved ETC for the VLT and various tools for the sky subtraction and fitting telluric features. The codes are written in ANSI-C, compliant use of ESO's CPL library, and contain ESO REFLEX workflows. They are also aimed for implementation into VLT and E-ELT data reduction pipelines. It is funded by the Austrian Ministry of Science (BM:wf).

Documentation of already approved deliverables are available via ESO's document repositories and homepages. An online version is installed at:
http://*www.eso.org/observing/etc/**sky**calc/**sky**calc.htm*

Features:

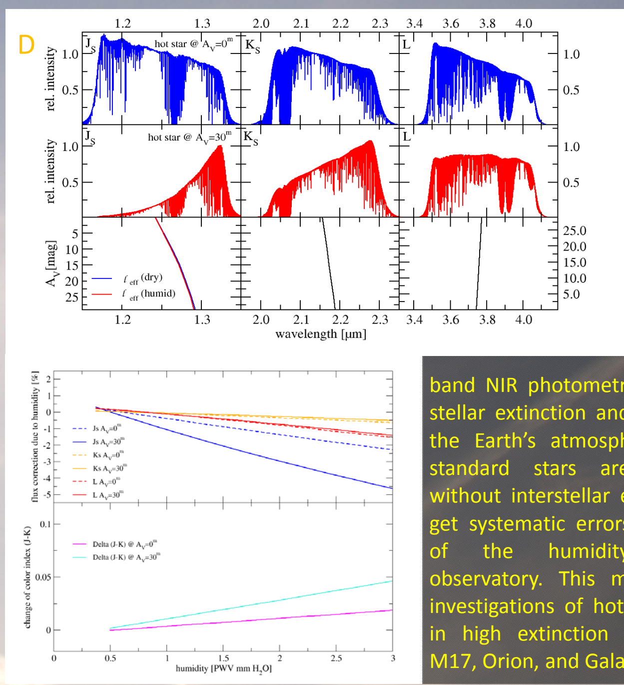
- ✓ Wavelength coverage from 0.3 to 30 µm
- ✓ Atmospheric extinction includes Rayleigh scattering, aerosol extinction (Patat et al. 2011, A&A, 527), and molecular absorption
- ✓ Absorption and emission in the lower atmosphere is calculated by the radiative transfer code LBLRTM (Clough et al. 2005, JQSRT, 91) for atmospheric profiles dependent on season and zenith distance
- ✓ 3D single scattering calculations with a multiple scattering correction were performed to derive relations for estimating the effective extinction of extended emission sources, like zodiacal light and airglow
- ✓ Spectroscopic extension and optimisation of the Krisciunas & Schaefer (1991, PASP, 103) model for scattered moonlight
- ✓ Mean spectrum of scattered starlight
- ✓ Zodiacal light model based on Leinert et al. (1998, A&AS, 127)
- ✓ Thermal telescope emission currently modelled as grey bodies
- ✓ Airglow line list based on Cosby et al. (2006, J. Geophys. Res., 111) atlas, OH calculations of Rousselot et al. (2000, A&A 354), and HITRAN database (Rothman et al. 2009, JQSRT 110)
- ✓ Airglow intensity and variability were derived from 1186 optical FORS1 spectra taken over 6 years (Patat 2008, A&A, 481)
- ✓ Airglow intensity dependent on zenith distance, solar radio flux, bimonthly period, third of the night, and variability class (green OI, NaID, red OI, OH, O_2, and continuum at 543 nm) (Fig. B)
- ✓ Mean airglow/residual continuum (Fig. C)



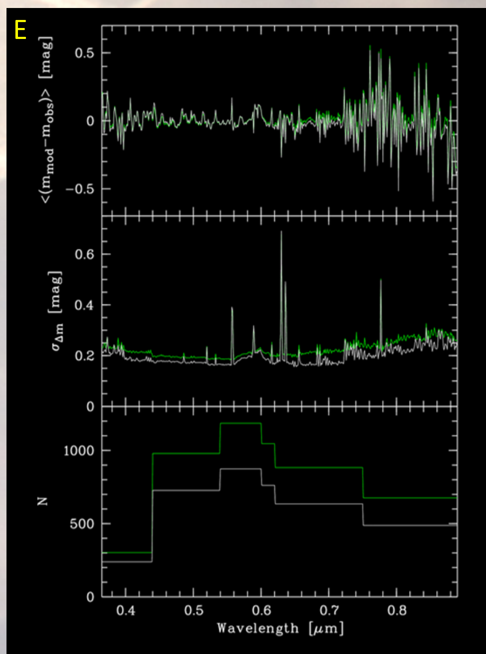
(C) Optical airglow continuum (white) and its variability (green) relative to the reference wavelength 543 nm. The most probable chemical reactions for the different continuum components are indicated. The nitric oxide continua show distinctly broader wavelength distributions than the iron-related pseudo continuum.

Status:

A comparison of the resulting model with observed photometric and spectroscopic data yields an accuracy of about 20 per cent for the ETC model (Fig. E), which is a significant improvement over previous models for Cerro Paranal (Noll et al. 2012, A&A, 543).
Status and updates will be provided at:
http://www.uibk.ac.at/eso/



(D) The change of effective wavelength of broad band NIR photometry with interstellar extinction and humidity in the Earth's atmosphere. As the standard stars are (normally) without interstellar extinction we get systematic errors as function of the humidity at the observatory. This mainly affects investigations of hot cluster stars in high extinction regions (e.g. M17, Orion, and Galactic Center).



(E) Deviations between our model and the FORS1 spectra of Patat (2008) in magnitudes. The mean difference in magnitudes (*upper*), the standard deviation (*middle*), and the number of spectra used for the different wavelengths (*lower*) are given.
The results for the full spectroscopic data set (green) and for spectra with the Moon below the horizon (white) are displayed separately.

(F) The night sky subtraction tested with FORS spectra (*left*) and SINFONI data (*right*). The models and predictions on line groups showing common variability by coupled physics are used to vary a sky template spectrum. This might be obtained using different conditions (nights). In addition to the variation of the night lines, a model based exact wavelength correction had to be calculated to avoid 'P-Cygni type' line features after subtraction.

The FORS spectrum used as data (black line) was obtained in November 2004. The sky template used here from calibration of the model was taken in June 2000 !
The SINFONI spectrum obtained in March 2006 was corrected using a sky template from October 2005.