CRIRES Science Verification Proposal

An Atlas of Titanium Oxide band heads in the J-band

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Abstract:

Spectral atlases and libraries have at all times been of great importance for the scientific progress in astrophysics. A library of observed spectra that has been built up with UVES at the VLT in recent years is the UVES Paranal Observatory Project (UVESPOP). We are currently using UVESPOP spectra of cool giant stars to measure precise wavelengths of Titanium Oxide (TiO) band heads. TiO is an opacity source of outstanding importance in late type stars. Despite its importance, a number of its band heads are still poorly reproduced regarding strengths and wavelengths in synthetic model spectra based on current theoretical line lists. This is a significant obstacle in the analysis of high-resolution spectra of cool objects. Up to now, no line list exists that consistently matches the positions and strengths of all TiO band heads. Our study will form a basis for the improvement of the theoretical understanding of the TiO molecule. We herewith apply for 145 min of observing time to extend the ongoing comparison beyond the red limit of 1.05 μm of the UVESPOP data. Thus, this project is also intended as a pilot study to general extension of the UVESPOP data base for cool stars to the NIR spectral region.

Scientific Case:

The diatomic molecule Titanium Oxide (TiO) is of highest astrophysical relevance. It forms in the atmospheres of cool objects and is a strong opacity source, thereby not only shaping the appearance of their spectra, but also playing a key role in the stratification of their atmospheres (Jørgensen, 1994, A&A 284, 179). Despite its high relevance, the theoretical description of transitions in TiO is still inadequate for a detailed comparison of observed and synthetic spectra at high resolution. Wrong line positions (Maness et al., 2006, astro-ph/0608260) and strengths of band heads (Reiners, 2005, AN 326, 930) strongly hamper, amongst others, the determination of basic stellar parameters of cool stellar objects.

We are currently undertaking a comparison between observed high-resolution spectra from the UVES Paranal Observatory Project (UVESPOP, Bagnulo et al., 2003, The Messenger 114, 10) and synthetic model spectra (list of Schwenke, 1998, Faraday Discussions 109, 321). Most of the band heads are matched well both in wavelength and strength. However, for some transition systems, a pronounced difference between predictions and observations has been found. Our aim is to provide a basis of measured band head wavelengths and strengths for an improvement of the theoretical modeling of the TiO molecule. Since the TiO opacity influences in turn the stratification of cool stellar atmospheres, this will also lead to an improvement of the description of these atmospheres.

The UVESPOP data base is a treasure trove for such investigations. Its limitation in wavelength arises from the red cut-off of the UVES detector at 1.05 μm. As described in Joyce et al., 1998, AJ 116, 2520, band heads of the TiO electronic ϕ system are situated in the near IR J-band of cool O-rich stars at about 1.1 – 1.3 μm. These are accessible at high resolution only with the CRIRES spectrograph. We herewith apply for 145 min of observing time to cover these band heads, to measure their precise wavelength, and to assess their strength in the theoretical line list. Since the work on the UVESPOP data is almost finished, the data acquired through this proposal will lead to prompt publication.

Furthermore, this proposal forms a pilot study for an extension of the UVESPOP data base to the NIR spectral region of cool stars. Via these two aspects, a considerable impact on the stellar scientific community can be expected.

The target selected for this proposal is the Semi-regular Variable star V1365 Ori (HD 34055) of spectral type M6. It is fully covered by the UVESPOP data base, thus a precise radial velocity measurement, indispensable to derive precise rest wavelengths, is available ($+42.7\,\mathrm{kms}^{-1}$). The target is quite high in the sky for the first few hours of the night at the time when SV observations are scheduled. The target is rather bright in the IR, the minimum DIT of 1 s is sufficient and safe when AO is applied. For all the 22 wavelength settings from 54/0/n to 44/0/i a ThAr calibration lamp exposure should be taken. Where available, also the atmospheric absorption lines will be used to cross-check the wavelength calibration.

To be scientifically useful, a reduced number of eight wavelength settings may be observed. These should include the settings 44/0/n and i, 45/0/n and i, 51/0/n and i, and 54/0/n and i. In this case, the observing time will be reduced to about 60 minutes.

Required observing time

Target	**RA**	**DEC**	**Wavelength Band**	**Magnitude**	**DIT**	**NDIT**
V1365 Ori	05 14 36.95	-00 33 46.23	1.03 – 1.30	J = 1.86	1 s	6

The object chosen is bright in the near IR (2MASS magnitude of $1\overset{\mathrm{m}}{.}86$ in the J band), thus the minimum DIT of 1 s is sufficient and safe. The SNR expected will be around 60/DIT which will secure reaching the science goals. Including a ThAr calibration lamp exposure for every wavelength setting between 54/0/n and 44/0/i (22 of them), we arrive at a time of 6.1 min per setting. Taking the recommended telescope overheads from the current CRIRES manual (telescope preset, acquisition with AO), the total time estimate amounts to 145 min. Since no precise absolute flux measurement is proposed, no standard star observations are required; day time flats for every setting will be sufficient for the flux rectification. To correct for the telluric line absorption, atmospheric transmission spectra calculated with the PC-LNWIN program will be used.