Measuring the Near-IR Airglow Continuum with Stray Light Reduced Spectrograph

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INTRODUCTION

The airglow continuum in near infrared is challenging to observe due to its faintness and the fact that the night sky spectrum is populated by a large number of bright hydroxyl (OH) emission lines. Typically, airglow continuum measurements have been carried out either with grating spectrographs or narrow band filters. The difficulty with narrow band filters is to find a band that is clean of atmospheric emission lines so resolving the emission spectrally is important.

However, grating spectrographs are known to suffer from scattered light produced by the grating itself[1]. In case of near infrared observations where large number of bright emission lines are present, the diffuse component of this scattered light can result in a significant artificial continuum confounding the measurement[2].

Here a new type of stray light reducing double pass echelle spectrograph design is presented with the main purpose to measure the airglow continuum.

The built concept design is based on an idea that was proposed as a design improvement for the ESO/VLT first generation high resolution spectrograph[3]. Essentially, it is a white-pupil echelle spectrograph with a “twist”.

The main limitation of the built spectrograph is that it utilises a CCD as a detector and thus has a spectral cutoff at 1100nm. The new design should bring the most benefits in J and H bands where the atmospheric OH lines are the brightest and the thermal background is still low.

CONCEPT

The base design is a textbook example of an astronomical high resolution echelle spectrograph with an additional right-angle prism between the 1st and the 2nd pass of the grating. The prism rotates the beam by 90°, effectively, re-directing the scattered light from the individual dispersion to 45° angle respective to the final spectrum. This scattered light, known as grating grass, can be masked in the secondary focus and the resulting spectrum is a clean and the scattered light does not affect the adjacent orders. The line spread profile (LSF) of the spectrograph has steeply decreasing wings and most of the remaining scattered light will originate from dust and micro roughness on the optical surfaces.

RESULTS

A concept design has been materialized and initial tests have been made. In the laboratory, the built spectrograph performs as expected providing a line spread function (LSF) with steeply falling wings and consequently high spectral purity.

The LSF has contrast of 6 orders of magnitude between the peak and the remaining diffuse scattered light. Away from the core of line, the LSF wings are 2 orders of magnitude fainter compared to the same grating used in single pass (Fig. 3).

First on-sky tests without the siderostat have been made by drift scanning on the sky. Proper measurements will be carried out the coming winter on the site of Observatorio Roque de Los Muchachos, La Palma, Canary Islands.

CONCLUSIONS

1. A new type of white-pupil echelle spectrograph has been demonstrated.

2. Initial test results are promising good performance indicating that the design in combination with OH suppression could offer significant improvement on the deep ground based NIR spectroscopy overcoming sky limitations of Extremely Large Telescopes (ELTs).

3. On-sky observing campaign will start later this year on site of Roque de los Muchachos, La Palma, Canary Islands and first results are expected to be published next year.

REFERENCES

3. M. I. Andersen and J. Andersen. Possible design features of a UV-near infrared VLT high-resolution spectrograph. ESO Proceedings, 1992

Fig. 1 (Left) Setup before sealing outer layer of the enclosure.
(Right) The collimated beam passes the grating twice and it is rotated between the dispersions. The scattered light will leave to different directions than the dispersed spectrum which is a vector sum of the individual dispersions. The scattered light from the grating follows the single dispersion directions whereas the twice dispersed beam will follow third direction being the vector sum of the two individual dispersions. With 90° beam rotation the scattered light will fall 45° from the spectrum. The scattered light can be masked out at an intermediate focus.

Fig. 2 Schematic layout of the optical design. The design is otherwise typical white-pupil echelle spectrograph but it additional right-angle prism between the two dispersions at the grating. Spectrograph has a built-in telescope on the optical bench.

The spectrograph has a built-in fixed telescope (2” achromatic doublet, f=750mm) on the optical bench. The entrance of the spectrograph is a 75μm pinhole, giving 20arcsec circular aperture on the sky. Due to the fixed telescope, the setup requires a siderostat to track on the sky. A simple siderostat has been made to accompany the spectrograph. The full system has not yet been successfully aligned but it is expected to be ready for an observing campaign this winter.

The spectrograph uses an EMCCD as a detector which will be used in photon counting mode[4]. The spectral coverage is from 550nm to the detector cut-off at 1100nm with resolving power of R~15 000.

Fig. 3 (Left) Spectrograph point spread function (PSF) on the top and line spread function (LSF) measured with HeNe laser (632.8nm) on the bottom. PSF The LSF has high contrast of 6 orders of magnitude between the core and the wings.
(Right) Spectral layout, the gap in the middle row of the detector is caused by the shadow of a mini prism which is located right behind the entrance pinhole, a drawback of the design.

Fig. 4 (Left) Spectral layout, the gap in the middle row of the detector is caused by the shadow of a mini prism which is located right behind the entrance pinhole, a drawback of the design.