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High-resolution échelle spectrograph at Skalnaté Pleso Observatory

T. Pribulla, M. Vaňko, R. Komžík and P. Sivanič

Astronomical Institute of the Slovak Academy of Sciences
059 60 Tatranská Lomnica, The Slovak Republic(E-mail: pribulla@astro.sk)

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Abstract. A clone of échelle spectrograph MUSICOS (MUlti-SIte COntinuous Spectroscopy) is mounted in the Nasmyth-Cassegrain focus of the 1.3m telescope at Skalnaté Pleso Observatory. The spectrograph is a cross-dispersed, bench-mounted, fiber-fed instrument giving a resolving power in the range of 25 000 to 38 500 (FWHM). Fifty-six orders cover the spectral range between 4250 and 7375 Å. The spectrograph is primarily used to observe novae, symbiotic stars, pulsating variables, binaries, and multiple stellar systems. The radial-velocity stability (100 – 200 $\mathrm{m\,s^{-1}}$) is sufficient to detect easily the orbital motion of hot Jupiters orbiting bright stars. In order to improve the spectrograph throughput and radial-velocity stability, several technical changes are planned in the near future.

Key words: instrument – spectrograph

1. Introduction

Skalnaté Pleso Observatory (20° 14′ 02″ E, 49° 11′ 22″ N, 1786 m a.s.l.) is one of the three observatories of the Astronomical Institute of the Slovak Academy of Sciences. Its bigger, 8 m dome shelters a 1.3 m ($f/8.36$) Nasmyth-Cassegrain telescope (Astelco GmbH, Germany). This is a fully automated instrument with an active optics system on a fast-slewing alt-azimuth fork mount. The first observations were performed in November 2016. The telescope is equipped with a fiber-fed échelle spectrograph following the MUSICOS design (Baudrand & Bohm, 1992). Its Fiber Injection and Guiding Unit (FIGU) is mounted in one of the Nasmyth foci of the telescope using a simple focal reducer to meet the focal ratio of the telescope ($f/8.36$) and collimator ($f/4$). The fiber fore-optics is telecentric. A simple video camera WATEC 120N is used to guide the telescope on the entrance of the 50 μm hole. The spectrograph throughput is mainly limited by strongly variable seeing at the site (1.5 – 4″). During times when seeing is <1.5″, part of the light is lost due to the point-spread-function imperfections.

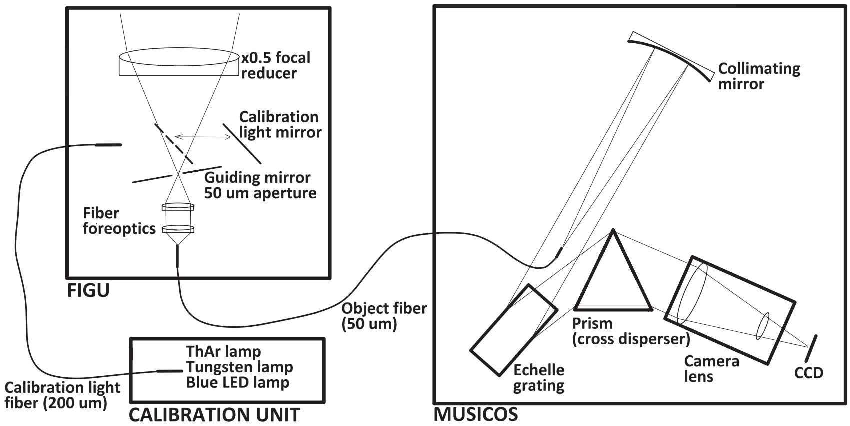

Figure 1. Schematic layout of the MUSICOS spectrograph.

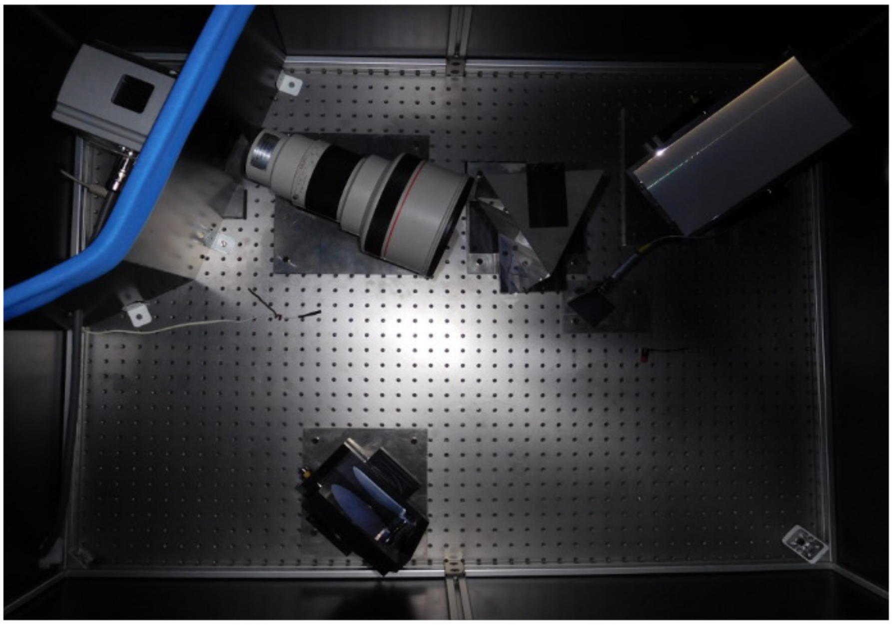

Figure 2. MUSICOS on the optical bench.

2. Components of the MUSICOS spectrograph

Fiber injection and guiding unit, fibers: Made by Shelyak, 200 μm calibration fiber, 50 μm object fiber (UV grade) – both multimode;

Calibration lamps: Thorium-Argon (ThAr), halogen lamp, and blue diodes in a unit made by Shelyak;

Collimator: $f/4$ (480 mm focal length) on-axis dielectrically multi-coated parabolic mirror;

Grating: 31.6 lines/mm, R2 échelle, 128×254 mm;

Crossdisperser: SF5 glass prism with 57° apex angle; optimized antireflection coatings on both sides;

Camera: Canon lens FD 2.8/400L;

Detector: Andor iKon-L DZ936N-BV CCD, 2048 × 2048 array, 13.5 μm pixels, read-out noise 2.9 e^{-}, with water assist -95 °C;

Spectral range: 4250-7375 Å in 56 échelle orders;

Spectral resolution: $R = 25\,000$ to $38\,500$ (FWHM), depending on the focusing

RV stability: 100-200 m.s^{-1}

3. Data reduction

The raw spectroscopic data are being reduced using IRAF package tasks, LINUX shell scripts, and FORTRAN programs. In the first step, master dark and flat-field frames are produced, based on the spectra from the tungsten lamp and blue LED. In the second step, the photometric calibration of the frames is performed using dark and flat-field frames. Bad pixels are cleaned using a bad-pixel mask, and cosmic ray hits are removed using the program of Pych (2004). Order positions are defined by fitting sixth-order Chebyshev polynomials to tungsten-lamp and blue LED spectra on the frames. The resulting two-dimensional (2D) spectra are then extracted and dispersion-solved using ThAr line positions. In the final step, 2D spectra are normalised to the continuum and combined to one-dimensional spectra.

4. Future prospects

It is planned to improve the capabilities of the spectrograph by (i) increasing its throughput, and (ii) improving its radial-velocity (RV) stability. Currently, the optical throughput of the spectrograph and telescope system is only around 3%. The typical signal-to-noise ratio (per pixel) for a $V = 11$ star is about 15 in a 900-second exposure. The largest light losses are due to seeing and fiber injection. The seeing losses are planned to be mitigated by using two-times thicker fiber (100 μm) and a 50 μm slit (on the spectrograph fiber end) and later using an image slicer to preserve the original spectrograph resolution. A direct injection of light to the fiber is also considered. This would exclude complicated aligning and light losses in the fiber foreoptics. The RV stability is planned to be improved using a bifurcated fiber enabling simultaneous ThAr calibration.

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