First Radial Velocity Measurements from the Spectra Obtained with a New BTA Fiber-Fed Spectrograph in the High Spectral Resolution Mode

T. E. Burlakova[1], G. G. Valyavin[1], V. N. Aitov[1], G. A. Galazutdinov[2,3], A. F. Valeev[1,4], A. V. Tavrov[5], A. E. Ivanova[5], O. I. Korablev[5], and J. L. Berto[5]

[1] Special Astrophysical Observatory, Russian Academy of Sciences, Nizhny Arkhyz, Russia
[2] Universidad Catolica del Norte, Antofagasta, Chile
[3] Central (Pulkovo) Astronomical Observatory, Russian Academy of Sciences, Saint Petersburg, Russia
[4] Crimean Astrophysical Observatory, Russian Academy of Sciences, Nauchny, Russia
[5] Space Research Institute, Russian Academy of Science, Moscow, Russia

Abstract. We present the first results of observations of radial velocity variability in stars using a new fiber-fed spectrograph with high spectral resolution (R = 35000–120000). Observations of a number of stars with characteristic stellar magnitudes from 8.5^m to 10.5^m were carried out in the mode covering the spectral resolutions from R45000 to R65000 with a simultaneous registration of the calibration spectrum of a thorium-argon hollow-cathode lamp. The characteristic measurement accuracies we have obtained ranged from a few to several tens of m/s. In the future, the thorium-argon lamp will be replaced with a Fabri-Pérot interferometer to reach the limiting radial velocity measurement accuracy in stars up to 1 m/s.

Keywords: techniques: spectroscopic; planetary systems

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Over April-June 2020, pilot spectroscopic observations of several sun-like stars with confirmed exoplanets and without them were carried out at the 6-m SAO RAS BTA telescope. The observations were carried out using a high-resolution fiber-optic spectrograph with the resolution from R45000 to R65000. The aim of the observations was to pilot run the instrument for the characteristic accuracy in measuring the radial velocities of stars from their spectra. This

communication presents the results of observations of the star HD93963 which is orbited by a giant recently discovered planet, whose radial velocity amplitude reaches the values of more than 400 m/s, as well as KOI-974 and KOI-2706, which are parent stars of exoplanets of intermediate and low masses with radial velocity variability amplitude of less than 30 m/s.

Figure 1 shows an echelle image obtained with the spectrograph. Each spectral order is represented by two spaced strobes, one of which gives the spectrum of a star, and the other—the spectrum of a thorium-argon lamp. The processing of such an image by the standard method is reduced to obtaining two extracted spectra obtained in one image: the spectra of the star and the thorium-argon lamp (a comparison spectrum). Simultaneous measurements of radial velocities from the spectral lines of the star and the comparison spectrum, carried out over the entire series of observations of a particular star, make it possible to estimate the Doppler variability amplitude of radial velocity of the star corrected for the mechanical instability of the instrument, which is controlled by the comparison spectrum.

Radial velocities of spectral lines were measured using the DECH software (http://www.gazinur.com/Download.html) package applying the method of one-dimensional cross-correlation according to the algorithm based on the Fourier transform proposed by Tonry & Davis (1979). The measurement error was estimated using the technique similar to that presented in the IRAF astronomical data processing system, taking into account the modification of the algorithm proposed in Verschueren & David (1999). The method is based on the approximation of the main peak of the correlation function by a second-order polynomial with a subsequent estimation of the intensity and width of the peak at the half of its intensity. Since we used one of the spectra of the star as the template spectrum, the error estimate is free from the unwanted effects caused by incongruence between the template and studied spectra.

The results of study are presented in Figure 2, where the solid line shows the radial velocity variability curve of the known exoplanet MASCARA-3 b. Black circles with dashes denote the results of radial velocity measurements of this exoplanet and the associated error bars according to our observations. The symbols of other colors indicate the results of radial velocity measurements of other solar-type stars that did not reveal any significant variations in their radial velocities. The accuracy of measuring the radial velocities in stars depends on their spectral type, brightness, and seeing, and varies from 4.7 to 20 m/s for solar-type stars. The inaccuracies in observations of the exoplanet Mascara-3b are traditionally higher due to its nonstationarity.

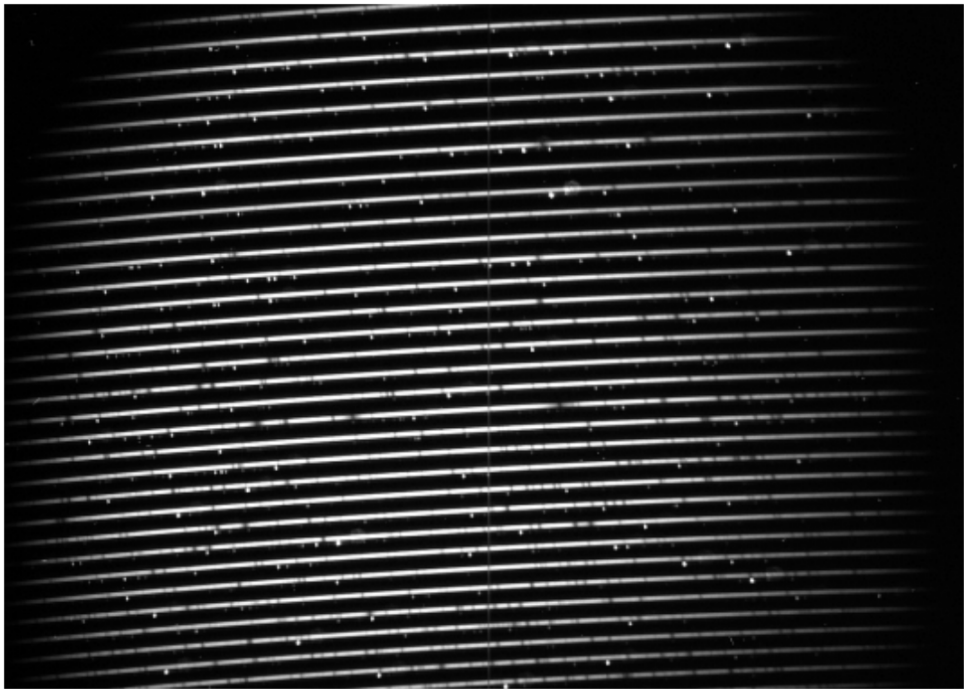

Fig. 1. An example of an echelle image, obtained with the spectrograph

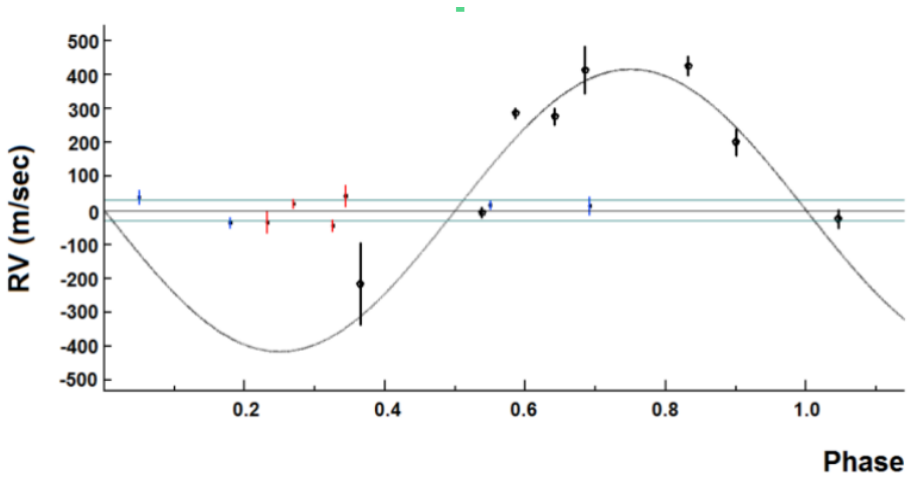

Fig. 2. Results of radial velocity variation measurements in stars with exoplanets.

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