Searching for Long-Period Exoplanets orbiting Giant Stars

at the Landessternwarte Heidelberg, Germany

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Application Note

Introduction

The exoplanet group at the Landessternwarte Heidelberg has recently built a high resolution spectrograph (Tala et al. 2016) that is capable of delivering precise radial velocity measurements. It has a resolution of about 65,000, and is used in conjunction with an iodine absorption cell as reference for the stellar radial velocity measurements. The fiber-fed spectrograph is attached to the 72 cm Waltz Telescope of the Landessternwarte, situated on top of the Königstuhl in Heidelberg at an altitude of 562 m. The Waltz Telescope (see Fig. 1) saw first light more than 110 years ago, in 1906, but is mechanically still in very good condition. Its electronics has been updated, so that it can conveniently be operated in a computer-controlled way. The project will allow bachelor and master students to actually carry out scientific observations.

Fig. 1
The dome of the 72 cm Waltz Telescope of the Landessternwarte on top of the Königstuhl in Heidelberg, Germany.

Goal

The goal of the Doppler survey which we are planning to carry out with the Waltz Telescope and Spectrograph is to find exoplanets around giant stars with rather long periods, as well as to characterize potential stellar companions to systems hosting already known exoplanets around giant stars. The targets for our Doppler survey were identified in a precursor survey carried out at Lick Observatory, USA, from 1999 to 2011, with a very similar setup. The survey at Lick Observatory lead to the discovery of 12 planets so far (see e.g. Frink et al. 2002 for the discovery of the first planet around a giant star, Trifonov et al. 2015 for a two planet system around a giant star, and Ortiz et al. 2016 for a planet in a close spectroscopic binary).

Iota Draconis

One example target which is very worthwhile to monitor further is iota Draconis (see Fig. 2). This giant star has an eccentric giant planet with on orbital period of 511 days, but on top of that a modulation with a rather long period (larger than 20-30 years) is visible which could be due to a brown dwarf, but further observations are necessary to confirm it. Identifying such long-term companions in systems with known planets provides constraints on planet formation theories.

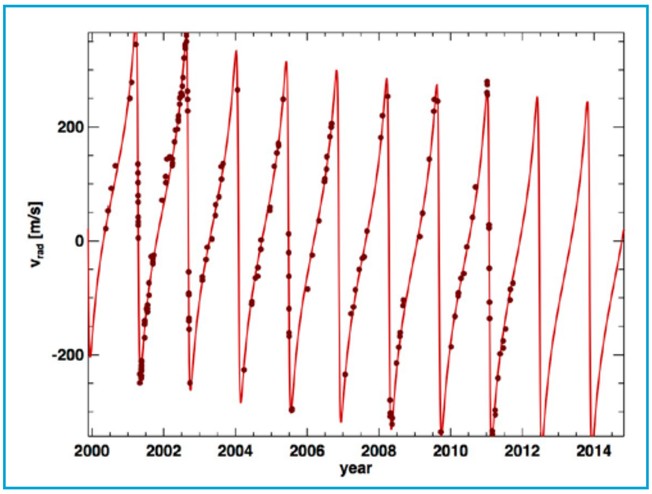

Fig. 2
Radial velocity curve of iota Draconis, obtained at Lick Observatory between 1999 and 2011. The periodic pattern in the radial velocities is caused by a giant planet, while the linear trend, visible mainly through the decreasing value in the maxima and minima radial velocities, is probably due to an additional brown dwarf in the system.

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Instrumentation

The high resolution spectrograph built by the Landessternwarte Heidelberg is shown in Fig. 3. The iKon-L 936 CCD detector (DZ936N-BV) can be seen in the lower left of that picture. The mounts of the grating (rectangular shape in the middle part of the picture) and the prism (triangular shape below the grating mount) can also be seen, as well as the 30 cm silver mirror serving as collimator on the right. The spectrograph is fiber-fed; the rectangular 25 x 100 micron fiber can also be seen in Fig. 3.

The spectrograph sits in its own room, but is not actively temperature- or pressure-controlled. Instead, we use an iodine cell, whose absorption lines serve as reference for the Doppler shift measurements.

The iodine lines are mainly located between 5000 and 6000 A.

Fig. 3

The fiber-fed high resolution spectrograph built by the Landessternwarte Heidelberg for the Waltz Telescope, with the camera and CCD detector attached in the lower left of the picture. In the middle of the picture, ones sees the metal mounts holding the grating (rectangular shape) and prism (triangular shape), while on the right one can see the 30 cm silver mirror used as collimator.

Arcturus Spectrum

A first spectrum with the new instrumentation was obtained on June 10, 2017, of the very bright K giant star Arcturus, which is one of our survey stars. The spectrum is shown in Fig. 4. The horizontally, curved lines are the various orders of the spectrograph, while the dark spots imprinted on these lines are the absorption lines. In order to measure the radial velocity with high precision (better than 5 m/s), the positions of many hundreds of such absorption lines have to be measured with a precision of a tiny fraction of a pixel. The relative precision achieved in the Doppler shift is about $2x10^{-8}$. The actual Doppler shift is obtained by combining a spectrum of the star, taken without iodine cell, with a spectrum of the iodine cell such that the observed spectrum of the star through the iodine cell at a given epoch is reproduced; the required shift between the stellar spectrum and the iodine spectrum corresponds to the Doppler shift.

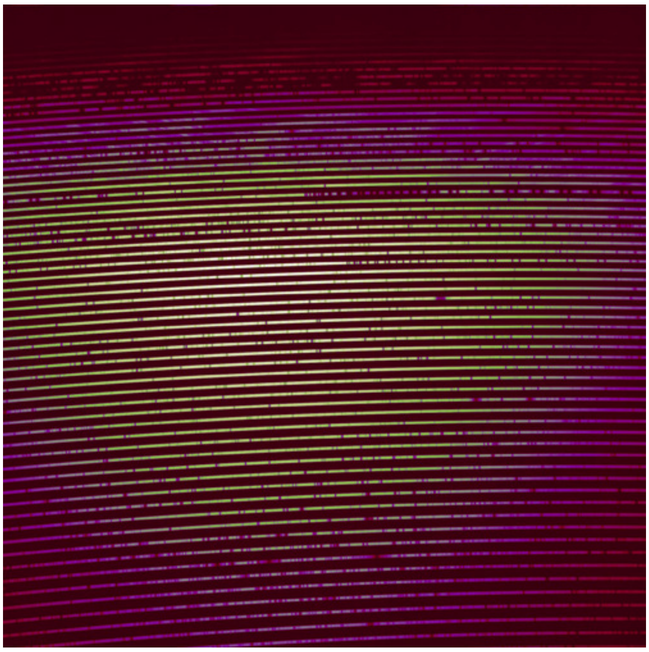

Fig. 4

The first stellar spectrum taken with our new spectrograph and the new CCD detector was of the very bright giant star Arcturus. The horizontally curved lines are the individual orders of the spectrum; the dark spots that can be seen throughout most orders are absorption lines. Most prominent are telluric absorption bands in the top part of the spectrum, but also the H alpha and the sodium D lines can be identified.

References

Sabine Frink, David S. Mitchell, Andreas Quirrenbach, Debra A. Fischer, Geoffrey W. Marcy, R. Paul Butler 'Discovery of a Substellar Companion to the K2 III Giant iota Draconis', ApJ 576, 478, 2002

Mauricio Ortiz, Sabine Reffert, Trifon Trifonov, Andreas Quirrenbach, David S. Mitchell, Grzegorz Nowak, Esther Buenzli, Neil Zimmerman, Mickaël Bonnefoy, Andy Skemer, Denis Defrère, Man Hoi Lee, Debra A. Fischer, Philip M. Hinz: 'Precise radial velocities of giant stars IX. HD 59686 Ab: a massive circumstellar planet orbiting a giant star in a ~13.6 au eccentric binary system', A&A 595, A55, 2016

Tala, M., Heeren, P., Grill, M., Harris, R.J., Stürmer, J., Schwab, C., Gutcke, T., Reffert, S., Quirrenbach, A., Seifert, W., Mandel, H., Geuer, L., Schäffner, L., Thimm, G., Seemann, U., Tietz, J., Wagner, K. 'A high-resolution spectrograph for the 72cm Waltz Telescope at Landessternwarte, Heidelberg', Proc. SPIE 9908, 2016

Trifon Trifonov, Sabine Reffert, Xianyu Tan, Man Hoi Lee, Andreas Quirrenbach 'Precise radial velocities of giant stars VI. A possible 2:1 resonant planet pair around the K giant star eta Cet', A&A 568, A64, 2014

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