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CARMENES: M Dwarfs and their Planets

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Abstract. CARMENES (**C**alar **A**lto high-**R**esolution search for **M** dwarfs with **E**xo-earths with **N**ear-infrared and optical **E**chelle **S**pectrographs) is a new instrument currently undergoing commissioning at the 3.5 m telescope of the Calar Alto Observatory. It has been constructed by a consortium of eleven Spanish and German institutions. The scientific goal of the project is a 600-night radial-velocity survey targeting 300 M dwarfs with sufficient precision to detect terrestrial planets in their habitable zones. The CARMENES instrument consists of two separate échelle spectrographs covering the wavelength range from 0.55 to 1.7 μm at a spectral resolution of $R = 82,000$, fed by fibers from the Cassegrain focus of the telescope. Both spectrographs are housed in a temperature-stabilized environment in vacuum tanks, to enable a long-term radial velocity precision of $1\,\mathrm{m\,s^{-1}}$. The wavelength calibration will be done with Th-Ne and U-Ne emission line lamps, and with Fabry-Pérot etalons.

Keywords. Planetary Systems, Spectrographs

1. Introduction

CARMENES is a new radial-velocity facility for the 3.5 m telescope of Calar Alto Observatory. The fundamental scientific objective of CARMENES is to carry out a survey of late-type main sequence stars with the goals of characterizing the population of planets around these stars, and of detecting low-mass planets in their habitable zones (HZs). In the focus of the project are very cool stars later than spectral type M4V and moderately active stars, but the target list will also comprise earlier and therefore brighter M dwarfs. In particular, we aim at being able to detect $2\,M_\oplus$ planets in the HZs of M5 stars. A long-term radial velocity precision of 1 m/s per measurement will permit to attain this

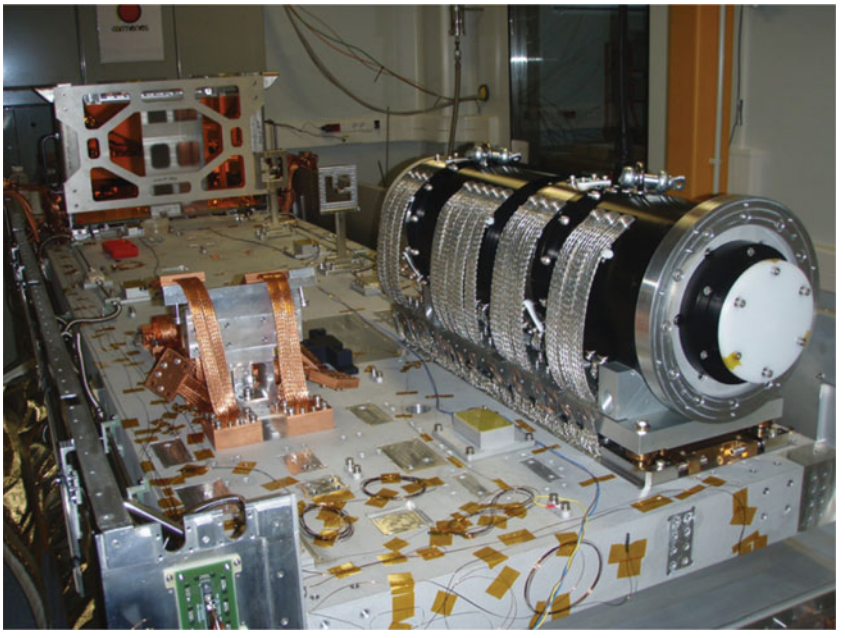

Figure 1. Integration of the optical bench of the near-IR spectrograph.

goal. Detailed descriptions of the CARMENES project are given in Quirrenbach *et al.* (2010, 2012, 2014) and the references therein.

2. The CARMENES Instrument

For mid-M to late-M spectral types, the wavelength range around 1000 nm (Y band) is a very suitable region for RV work, since here the stars are bright, the spectra are rich in absorption lines, and telluric contamination is not too severe. Therefore, the efficiency of CARMENES has been optimized for this range. Since CCDs do not provide high enough efficiency above 900 nm, a near-IR detector is required. It is thus natural to adopt an instrument concept with two spectrographs, one equipped with a CCD for the range 550 – 1050 nm, and one with HgCdTe detectors for the range from 0.95 – 1.7 μm. This very wide simultaneous wavelength coverage makes it possible to distinguish achromatic radial-velocity variations induced by planetary companions from stellar variability, which is usually stronger at visible wavelengths than in the infrared.

Each spectrograph is coupled to the 3.5 m telescope with its own optical fiber link, consisting of a long fiber with circular cross section, and a shorter octagonal fiber. This combination provides for excellent scrambling of the fiber input. The front end contains a dichroic beam splitter and an atmospheric dispersion corrector. Additional fibers are available for simultaneous injection of light from emission line lamps and Fabry-Pérot etalons for RV calibration.

The spectrographs are mounted on benches inside vacuum tanks (see Fig. 1), which are located in climatic chambers inside the coudé laboratory of the 3.5 m dome. The near-IR vacuum tank is equipped with a temperature stabilization system; the thermal design of both spectrographs provides the capability of keeping the temperature of the optical bench constant to within ± 0.01 K over 24 h. The visible-light spectrograph is operated near room temperature, the NIR spectrograph is cooled to ~ 140 K.

Figure 2. The near-infrared spectrograph was moved to Calar Alto Observatory and installed in the coudé laboratory of the 3.5 m telescope on Oct 20, 2015. The vacuum tank of the visible-light spectrograph is nearly identical; it was installed already in August.

3. Installation at Calar Alto and First Light

The subsystems of CARMENES were moved to Calar Alto and installed at the 3.5 m telescope in the course of 2015. The front end was mounted at the Cassegrain flange in April, followed by extensive testing of the acquisition and guiding procedures and the software interfaces with the telescope control system. The optical fibers connecting the front end to the spectrographs were routed through the telescope fork at the same time. The visible-light spectrograph was shipped to the observatory July. The optical bench and the vacuum system had been separately pre-integrated at Landessternwarte Heidelberg and at the Max-Planck-Institut für Astronomie, respectively; they were first integrated with each other on site. The near-infrared spectrograph was fully integrated at the Instituto de Astrofísica de Andalucía and moved to Calar Alto in October (see Fig. 2). The calibration system and the Fabry-Pérot etalons were installed in parallel. CARMENES had "First Light" – defined as taking stellar spectra with both spectrographs simultaneously – on Nov 9, 2015. This event marked the beginning of the commissioning, in which the whole instrument will be tested and characterized. The CARMENES M dwarf survey will begin on Jan 1, 2016.

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