Abstract. With the example of Proxima Centauri we discuss the feasibility of detecting terrestrial planets (1 to a few $M_\oplus$) using the high precision radial velocity ($RV$) technique. If a very high $RV$ precision for M stars is achieved even planets with these extremely low masses become detectable. For Proxima Cen (M5V), one of the prime targets of our M-stars planet search program using the UVES spectrograph & iodine cell at the ESO VLT UT2, we obtain a long term $RV$ precision of 2.5 m s$^{-1}$. Based on numerical simulations we determine that this level of precision would have already allowed us to detect planets with $m \sin i = 4$ to $6 M_\oplus$ inside the habitable zone of Proxima Cen.

1. Introduction

All extrasolar planets orbiting main-sequence stars known to date are giant planets ranging in mass from $m \sin i = 0.12 M_{\text{Jupiter}}$ to 17 $M_{\text{Jup}}$ (with $i$ the unknown angle between the orbital plane and the sky). It is virtually impossible
to detect terrestrial planets (rocky objects of 1 to a few M$_\oplus$) around F, G and K-type stars using the high-precision RV technique, since Earth-mass planets induce only negligible reflex-motions on their host stars. This scenario changes in the faint and low-mass regime of the Hertzsprung-Russell diagram. In the case of M-dwarf stars the low stellar primary mass leads to detectable RV amplitudes even for planets of a few M$_\oplus$ and less in short-period orbits. Fig.1 shows the RV signatures of planets with $m\sin i = 1$ M$_\oplus$ (solid), 1.5 M$_\oplus$ (dashed) and 2 M$_\oplus$ (dotted curve) residing in circular orbits. The vertical dashed lines show the borders of the habitable zone for this type of star after Kasting et al. (1993).

2. Searching for terrestrial planets inside the habitable zone of Proxima Centauri

For the past two years we have used the ESO VLT and the UVES spectrograph to monitor a sample of M-dwarf stars in the southern hemisphere to search for planetary companions. Our RV results for Proxima Cen (M5V, $V = 11.05$), obtained with an enhanced version of our Austral radial velocity code (Endl,
Figure 2. Differential radial velocity measurements of Proxima Cen obtained with the UVES spectrograph & iodine cell at the ESO VLT UT2 telescope. We find a linear acceleration of unknown origin (dashed line), the rms-scatter around this trend is 2.5 m s⁻¹.

Kürster, & Els 2000), are displayed in Fig.2. Over the time span of more than one year the star experiences a linear acceleration of unknown origin. The rms-scatter around this trend is 2.5 m s⁻¹.

2.1. Detection sensitivity

We then take the 22 RV-measurements (after subtraction of the linear trend) and determine our planet detection threshold in the period range for orbits inside the habitable zone (2 to 16 days), using the technique from Endl at al. (2001). For the primary mass we adopt a value of 0.11 M☉ after Henry et al. (1999).

Fig.3 shows our momentary detection capability based on the RV data collected so far. With a confidence of >99% we could have already detected all planets with m sin i values higher than 4 to 6 M⊕ inside the habitable zone. With a chance probability of ≈ 50% (i.e. only half of the test signals were recovered successfully with a confidence of >99%) we would have even found signals of planets down to m sin i ≈ 2.5 M⊕. These new constraints on planets inside the habitable zone of Proxima Cen supplement the existing limits for giant planets around this star by our ESO CES planet search program (Kürster et al. 1999) and the HST Fine Guidance Sensor astrometric results of Benedict et al. (1999).

3. Conclusions

Measuring radial velocities of M-dwarfs with the appropriate high level of precision allows us to detect extremely low-mass planets in short period orbits. With the 22 RV measurements we obtained so far for Proxima Cen, we could have
Figure 3. Detection threshold for low-mass planets orbiting inside the habitable zone of Proxima Cen. The solid thick line denotes the limit where we could have detected all planets with a confidence of > 99%. Hence we can exclude the presence of planets with $m \sin i$ values on and above this line. The dashed line shows the limits where we had a 50% chance of detection.

already detected all planets with $m \sin i = 4$ to $6 \, M_\oplus$ inside the habitable zone. So the answer to the title question is: not yet, but we get pretty close, and our sensitivity will further improve by extending the monitoring time span.

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