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# Detectability of rocky planets with ELT infrared spectroscopy

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**Abstract.** Brown dwarfs and very low-mass stars are likely to harbour planetary systems with rocky planets. We discuss the possibility of detecting them using accurate radial velocity measurements with a cross-dispersed high-resolution spectrograph coupled to a ground-based extremely large telescope.

**Keywords.** Stars: low mass, brown dwarfs; Planets: exoplanets; Techniques: spectroscopic.

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## 1. Introduction

Precise radial velocity (RV) measurements of stars have led to the discovery of more than 140 extrasolar planets. The frequency of planets with masses $m \sin i \geqslant 0.3\, M_{Jup}$ orbiting old G and K-type stars at distances of $\leqslant$5 AU is about 7%. In a few cases (Charbonneau *et al.* 2000; Alonso *et al.* 2004), eclipses have been observed which confirm that these objects **are** planets. Additionally, in the case of Gl 876, the planetary masses of the companions are confirmed by astrometric observations (Benedict *et al.* 2002).

In contrast to the planets of the solar system, the eccentricity of exoplanets is usually high. There seems to be little, if any, difference between the eccentricity distribution of exo-planets and binary stars. Another surprise was that there are massive planets at very small distances from the host stars. Last, but not least, studies of the metallicity of the host stars showed that the frequency of planets is higher for very metal rich stars (Santos, Israelian & Mayor 2001).

The new discoveries have inspired a large number of theoretical efforts aimed at explaining the observational properties of exoplanets. Planet formation models appear divided in basically two different fronts: giant planets may form either by a gravitational instability of the disk, or by core accretion of planetesimals until a 10 $M_{Earth}$ planet is formed and has enough gravitational pull to accrete gas from the nebula (see Wuchterl, Guillot & Lissauer 2000 for a review). The strange properties of the known exoplanets have been interpreted as evidence that planets form in both ways.

However, all these results are based on studies of old, solar-like F-K stars, which all have about one solar mass. Few radial velocity surveys for planets around M-stars have been carried out (Delfosse *et al.* 1998; Butler *et al.* 2004) but only 4 exoplanets have been detected so far. Remarkably, two of them are among the lowest mass exoplanets found to date, with minimum masses in the range 5-21 earth masses (Rivera *et al.* 2005). These surveys of M-stars are limited to small samples because they use optical spectrographs, and they are hampered by the high activity levels of many targets.

Surveys of visual companions of brown dwarfs (BD) have already identified a number of BD-BD binaries (Bouy *et al.* 2003; Martín *et al.* 2003) and one planet around a BD (Chauvin *et al.* 2005). The first dynamical masses of BDs have been obtained from orbital monitoring of some of these binaries (Bouy *et al.* 2004; Zapatero Osorio *et al.* 2004). Additionally, a spectroscopic BD-BD binary in the Pleiades has also been found (Basri & Martín 1999). This binary consists of two BDs with masses of 0.06 to 0.07 $M_\odot$ and an orbital period of 5.8 days. By searching for close BD-BD companions, one might hope to find an eclipsing binary which will then allow the determination of the accurate masses and radii.

BDs have accretion disks when they are young, and thus might also form planets (Barrado y Navascués & Martín 2003). If the disk of BDs are just scaled down versions of disks of young stars, we may speculate that the resulting planets are just scaled down versions of the planets of stars. In this case, 10% of the BDs should have planets with a mass of a few $M_{Earth}$. Since also the snow-radius of the disk scales with the mass of the central object, such planets would be located at a distance of $\leqslant$0.1 AU from the BD (Stevenson & Lunine 1988). Another view is that the planetary systems of BDs could be scaled up version of the Jovian moon-system. In contrast to our planetary system, where most of the angular momentum is in Jupiter, and not in the sun, in the case of the Jovian moon-system most of the angular momentum is in Jupiter, and not in its moons. If the planetary systems of BDs resemble the Jovian moon-system, we would again expect planets of a few $M_{Earth}$ but at much closer distance from the central object. The third possibility, of course, is that the distribution of companions is continuum, so that BDs also have planets of $M_{Jup}$. In any case, we expect that possible planets have periods of 40 days or less, which implies that they have to be searched for by means of RV-monitoring.

## 2. The advantage of an echelle NIR spectrograph with an ELT

One of the great advantages of an ELT will be the ability to achieve the highest possible accuracy for RV-measurements. As long as the width of the spectral lines is smaller than the resolution of the spectrograph, and assuming that the photospheric lines are evenly spread over a wide spectral range, the accuracy of the RV-measurement in $\mathrm{m\,s^{-1}}$ is given by:

$$\sigma = 1.45\,10^9\,(S/N)^{-1}\,R^{-1}\,B^{-1/2} \tag{2.1}$$

where $R$ is the resolution of the spectrograph, $(S/N)$ the signal-to-noise ratio of the spectrum, and $B$ the length of the spectral region that is being used. Thus, in order to achieve the highest possible RV-accuracy it is thus desirable to observe a part of the spectrum which is as wide as possible and a telescope that is as large as possible.

We are developing an echelle near-infrared spectrograph for the 10.4-meter telescope GranTeCan (GTC). This instrument called NAHUAL is being optimized for high-RV precision work (Martín *et al.* 2005). At a spectral resolution of R=80 000, we estimate that NAHUAL can reach a RV-precision (1 $\sigma$) of 2 $\mathrm{m\,s^{-1}}$ for an M6 dwarf with a J-band magnitude of 10. A 30-m ELT could reach a RV-precision of 0.6 $\mathrm{m\,s^{-1}}$ for the same dwarf, allowing to detect lower mass planets. These RV accuracies would allow to detect rocky planets within the habitable region of late-M and L-dwarfs.

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## References

Alonso, R. *et al.* 2004, *ApJ* 613, L153
Basri, G. & Martín, E.L. 1999, *AJ* 118, 2460
Barrado y Navascés, D. & Martín, E.L. 2003, *AJ* 126, 2997
Benedict, G.F., *et al.* 2002, *ApJ* 581, 115
Bouy, H. *et al.* 2003, *AJ* 126, 1526
Bouy, H. *et al.* 2004, *A&A* 423, 341
Butler, R.P. *et al.* 2004, *ApJ* 617, 580
Charbonneau, D. *et al.* 2000, *ApJ* 529, L45
Chauvin, G. *et al.* 2005, *A&A* 438, L25
Delfosse, X. *et al.* 1998, *A&A* 338, L67
Martín, E.L. *et al.* 2003, *ApJ* 594, 525
Martín, E.L. *et al.* 2005, *AN* 326, 1015
Rivera, E. *et al.* 2005, *ApJ* 634, 625
Santos, N.C., Israelian, I. & Mayor, M. 2004, *A&A* 415, 1153
Wuchterl, G., Guillot, T. & Lissauer, J.J. 2000, in: V. Mannings & A.P. Boss (eds.), *Protostars and Planets IV*, (University of Arizona Press, Tucson) p. 1081
Zapatero Osorio, M.R. *et al.* 2004, *A&A* 615, 958

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