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# A search for faint companions of the nearest stars with CanariCam and VHS

B. Gauza[1,2], V. J. S. Béjar[1,2], R. Rebolo[1,2], A. P.érez-Garrido[3], N. Lodieu[1,2], C. Álvarez[1,2], and on behalf of the UCD group of the VHS and substellar group of the CCST

[1] Instituto de Astrofísica de Canarias (IAC), E-38200 La Laguna, Tenerife, Spain
e-mail: bgauza@iac.es
[2] Dept. Astrofísica, Universidad de La Laguna (ULL), E-38206 La Laguna, Tenerife, Spain
[3] Universidad Politécnica de Cartagena, Campus Muralla del Mar, Cartagena, Murcia E-30202, Spain

**Abstract.** After two decades of discoveries, the census of substellar objects in the solar neighborhood remains incomplete. Current imaging surveys carried out in the near and mid-infrared are expected to unveil numerous ultracool dwarfs and expand the population to previously undetectable temperature ranges. Here we present a review of our searches for substellar companions around stars in the solar vicinity (d<10 pc). The searches are based on the southern near-infrared VISTA Hemisphere Survey (VHS) combined with WISE and 2MASS catalogues and on a deep mid-IR imaging program carried out with CanariCam at the 10.4m GTC, in the Northern sky. We achieve sensitivity and resolving power that enables us to detect early Y dwarfs ($T_{\rm eff}$ ~300-500 K) at separations larger than 10 AU.

## 1. Introduction

The coolest substellar objects are the so-called T dwarfs (1500-500K), and the new suggested Y dwarfs (< 500 K; Cushing et al. 2011). Up to now, 355 T dwarfs and 15 Y dwarfs (Cushing et al. 2011; Liu et al. 2011; Kirkpatrick et al. 2012; Tinney et al. 2012) are known, most of them are field dwarfs that have been found in isolation. Since the properties of substellar objects evolve with time, it is difficult to determine their masses without any knowledge of the age and distance. Brown dwarf companions of stars offer a unique opportunity to determine their physical properties and test evolutionary models.

We aim at exploring the transition zone between the brown dwarf and planet regimes. Conducted survey comprises two major parts: southern, where we use VISTA VHS data, and northern, where we carry out the CanariCam deep, high spatial resolution, mid-IR imaging program. Following sections give more details on the searches together with some first results.

## 2. Southern sky: VISTA Hemisphere Survey

The VISTA Hemisphere Survey (VHS) is a near-infrared public survey intended to

*Send offprint requests to*: B. Gauza

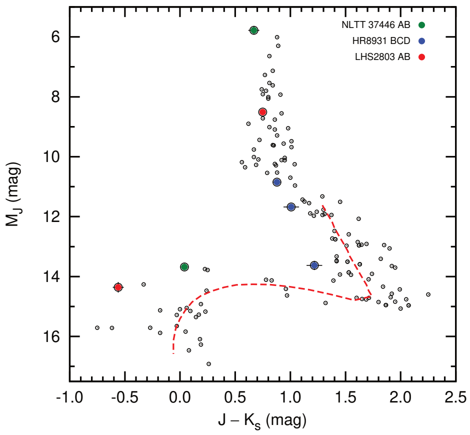


**Fig. 1.** $M_J$ vs. $J - K_s$ color-magnitude diagram of the three systems with new very low mass companions. Plot includes known M, L and T dwarfs with parallaxes and the mean L, T sequence (Vrba et al. 2004; Kirkpatrick et al. 2011).

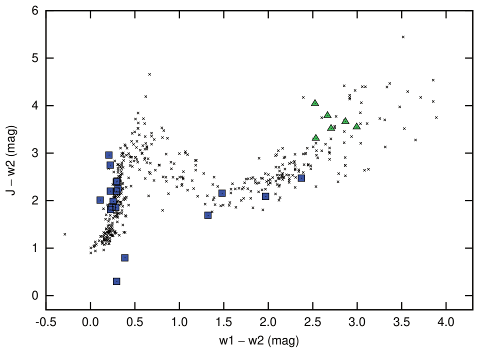


**Fig. 2.** $J - w2$ vs. $w1 - w2$ color-color diagram of several companion candidates identified so far. Squares and triangles represent common proper motion candidates and candidates selected using VHS and WISE photometric colors, respectively. Known field L and T dwarfs are plotted with black points.

cover the entire Southern hemisphere ($\sim 20,000\,\mathrm{deg}^2$) in the $JK_s$ broad band filters with a sensitivity more than 3 magnitudes deeper than 2 Micron All Sky Survey (2MASS). It uses the 4.1-m telescope VISTA (Visible and Infrared Survey Telescope for Astronomy) operating since 2009 at ESO's Cerro Paranal Observatory in Chile.

In our searches we combine VHS with 2MASS and WISE to identify common proper motion companions. VHS and 2MASS observations are separated typically by ~12 years. This time baseline allows to determine the proper motions with an accuracy better than 30 mas yr$^{-1}$. We select candidates with the typical colors of T and Y dwarfs: $J - w2 > 1.5$, $w1 - w2 > 2.5$ and $J - Ks < 1.0$.

### 2.1. First results

We discovered the fourth, very low-mass component in the HR 8931 star system (Gauza et al. 2012), formed by an F8V, metal-poor primary ([Fe/H] = −0.26), and a distant M8V + L3V pair. We found a faint ($J = 13.76 \pm 0.04$ mag) co-moving companion of the F8 star located at angular separation of $12.13 \pm 0.18$ arcsec, corresponding to a projected distance of ~317 AU at 26 pc. We determined this new companion to be an L1±1 dwarf with effective temperature of 2100-2300 K. Mass of the new companion is estimated at ~0.08 $M_\odot$, which places the object close to the stellar-substellar borderline. This multiple system provides an interesting example of coeval objects with masses slightly above and below the hydrogen burning mass limit.

We re-discovered the LHS 2803B (Deacon et al. 2012), the T5.5 common proper motion companion of the M4.5V star LHS 2803, located at an angular separation of 67″(~1600 AU).

Recently we have identified a likely brown dwarf companion to a planet host star NLTT 37446 (see Fig. 1).

We identify several common proper motion companion candidates, which will be subject to follow-up imaging and spectroscopic observations in order to be confirmed and characterized (see Fig. 2).

## 3. Northern sky: CanariCam imaging program

CanariCam is a mid-infrared instrument operating at the 10.4m Gran Telescopio Canarias (GTC). CanariCam was built by the University of Florida and it is designed to reach the

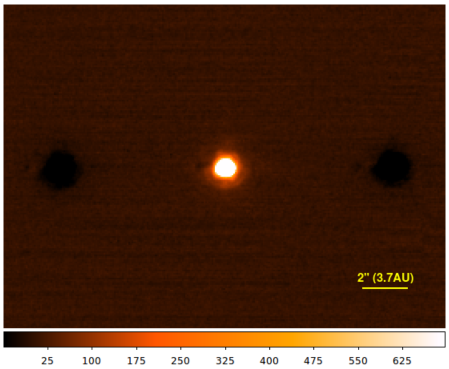


**Fig. 3.** 8.7 $\mu$m image of Barnard's star taken with CanariCam. We achieved sensitivity of ~12.0 mag (~0.8 mJy), with total on-source time of 1.3 h. FWHM is 0.27 arcsec.

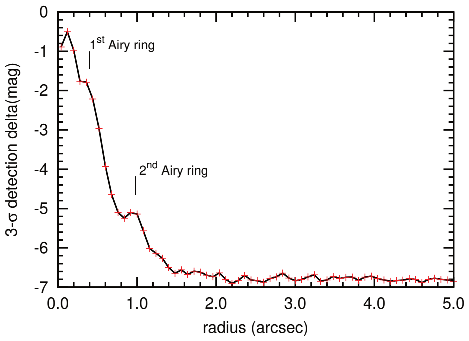


**Fig. 4.** CanariCam detectability curve for Barnard's Star. We reach contrast of 7 magnitudes at a separation of 2 arcsec.

diffraction limit of the GTC at mid-IR wavelengths (8-25$\mu$m). Our program carried out with CanariCam (PI: R. Rebolo) is based on deep, high spatial resolution imaging of the nearest stars (d<6 pc) at 10 $\mu$m. Currently we have data of 8 stars, including Barnard's Star. The reduced image and detectability curve of this object are shown in Fig. 3 and Fig. 4, respectively. With total on-source time of 1.3 h we achieved sensitivity of ~12.0 mag (~0.8 mJy), reaching a contrast of at least 7 mag at a separation >1.5 arcsec. This translates to objects of ~20$M_{\rm Jup}$ (solar age) at a projected distance larger than ~2.7 AU.

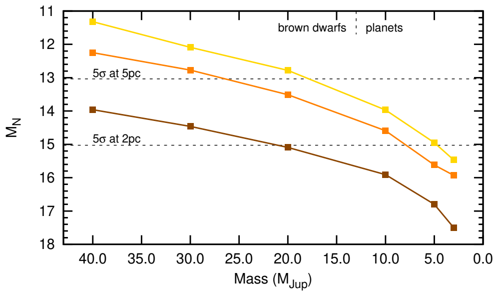


**Fig. 5.** Absolute N-band magnitudes of brown dwarfs and giant planets at (from top to bottom) 0.5, 1.0 and 5.0 Gyrs from Burrows et al. (1998) models. Dashed horizontal line mark the estimated sensitivity of CanariCam (N-band). Up to 10 pc we are able to detect objects with masses above 20 $M_{\rm Jup}$ and as old as 5.0 Gyr.

### *3.1. Summary & final remarks*

– We are conducting a search for faint, low-mass companions of nearby stars using VHS, WISE and 2MASS in the southern hemisphere and with CanariCam@GTC in the northern hemisphere;

– We are able to detect $m > 20M_{\rm Jup}$ objects with ages below 5 Gyr (Fig. 5) in the inner regions of the primaries using CanariCam (at separations greater than 10 AU) and at wider separations using VHS;

– Our main objective is to detect and characterize nearby companions with temperatures below 600K and to estimate the frequency of the coolest companions in the solar neighborhood.

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