Preparation of the CARMENES Input Catalogue: Multiplicity of M dwarfs from Tenths of Arcseconds to Hundreds of Arcminutes

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Abstract. With the help of CARMENCITA, the CARMENES Cool dwarf Information and daTa Archive, we investigate the multiplicity of M dwarfs in the solar neighbourhood observable from Calar Alto to prepare and characterize the final sample of CARMENES stars. Our multiplicity study covers a wide range in projected physical separations, from 0.5 to 55 000 au. The inner range is covered with a lucky-imaging survey of 385 M dwarfs with FastCam at the 1.5 m Telescopio Carlos Sánchez, complemented with a literature search. We explore visual or physical companions from 0.15 to 18 arcsec around our targets. These observations are important to discard very close companions that may induce spurious variations in the radial velocity of the primary and mimic the presence of planets. The outer range is covered with a detailed analysis of Washington Double Stars catalogue data and optical images taken by us with TCP and CAMELOT at the 0.8 m IAC80 telescope, and an astrometric study of all-sky public images and catalogues. We review the main results of our searches and derive the multiplicity of M dwarfs at close and wide physical separations.

1. Introduction

The CARMENES instrument is a next-generation radial-velocity instrument optimized for planet searches of mid- to late-type M dwarfs for the 3.5 m telescope at the Calar Alto Observatory, which is beeing built by a consortium of several Spanish and German institutions (Quirrenbach et al. 2012).

CARMENCITA is a comprehensive database of almost 2 200 M stars that contains information on all relevant properties of the potential targets, such as spectral type, photometry, multiplicity, $v \sin i$ activity, X-ray, etc., useful to select the least-active, brightest, latest M dwarfs with no companions at less than 5 arcsec (a separation at which the flux of any visual of physical companion could affect the radial-velocity measurement of the main target) observable from Calar Alto. To this purpose, we take high-resolution imaging and spectroscopy in order to identify and discard very close binaries, fast rotators and very active stars. In particular, in this proceeding, we look for unknown resolved binaries with new high- and low-resolution imaging and virtual observatory data.

2. Lucky imaging of close pairs with FastCam at 1.5 m TCS

FastCam is a lucky imaging instrument with a pixel scale of 42.3 mas/pix at the 1.5 m Telescopio Carlos Sánchez (TCS) at the Observatorio del Teide (Oscoz et al. 2008) used to obtain I-band imaging of 385 mid- to late-M dwarfs on 19 nights since Oct 2011 to May 2014. For each target, we took 10 000 frames of 50 ms. We aligned and combined all of them, as well as the best 1, 10 and 50 % raw frames, using the brightest pixel (Fig. .1).

About 69 % of the targets were single, 21 % had confirmed or probable physical companions in the range 0.15–17.70 arcsec and the remaining 10 % had possible background sources or artifacts that needed extra analysis. We provide new astrometric epochs for over 70 pairs (of which two are discordant with published values) and discover eight new pairs. Twenty physical companion candidates (including three new) have estimated periods shorter than 10 years.

3. Imaging of wide pairs with TCP (and CAMELOT) at 0.8 m IAC80

With the Tromsø CCD Photometer (TCP, 0.537 arcsec/pix) and the Cámara Mejorada Ligera del Observatorio del Teide (CAMELOT, 0.304 arcsec/pix) we observed in R-band 54 pair candidates with at least one M dwarf during a semester in 2012 (Fig. .2). After a

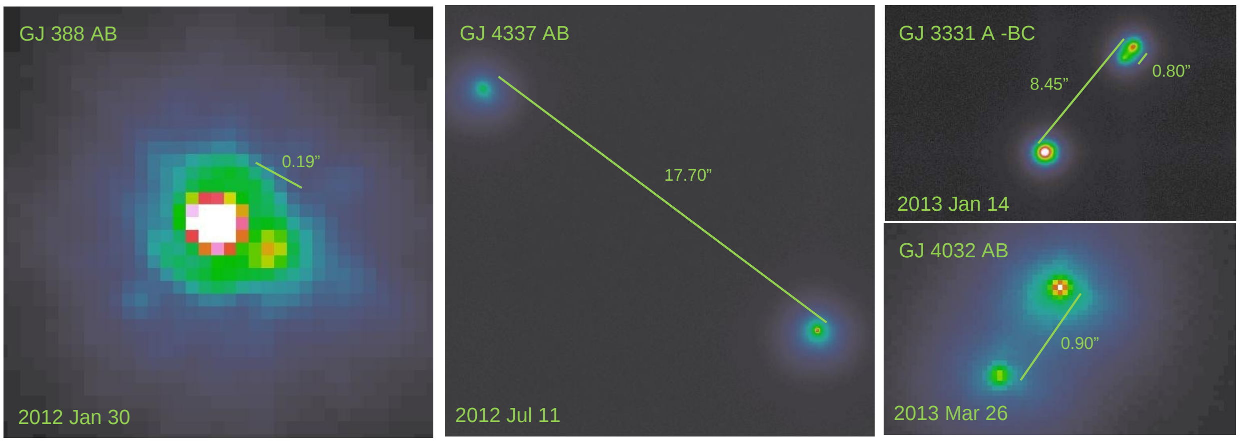

Figure .1: FastCam I-band images. Left panel: close pair in the quadruple AD Leo system (GJ 388). Middle and top right panels: previously known triple M-dwarf systems G 190-028 (GJ 4337) and BD-21 1074 (GJ 3331). Bottom right panel: possible physical companion of G 183-010 (GJ 4032).

comprehensive astrometric analysis, we confirm the physical binding of 52 pairs for which we provide projected physical separations, individual masses, reduced orbital periods and binding energies (Cortés-Contreras et al., in prep.).

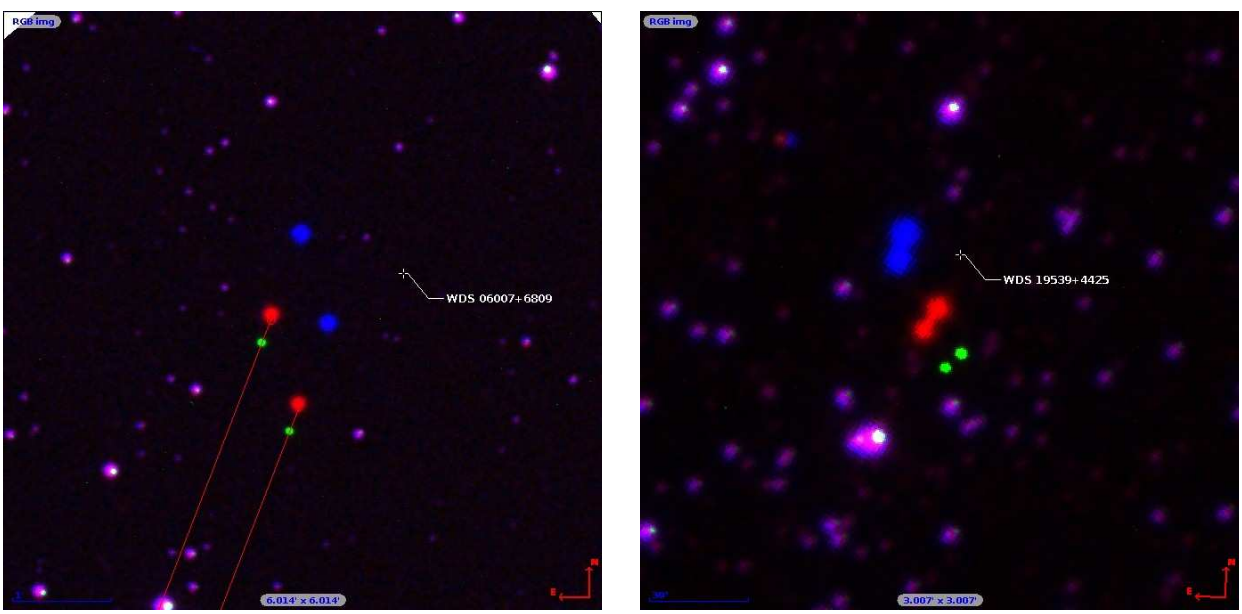

Figure .2: False-color composite images of two high proper-motion pairs, LP 057–041 AB and V1581 Cyg AB (blue: POSS-I 1950, red: POSS-II 1990, green: IAC80 2012). The right pair shows a clear relative movement, which is useful to track orbital variations.

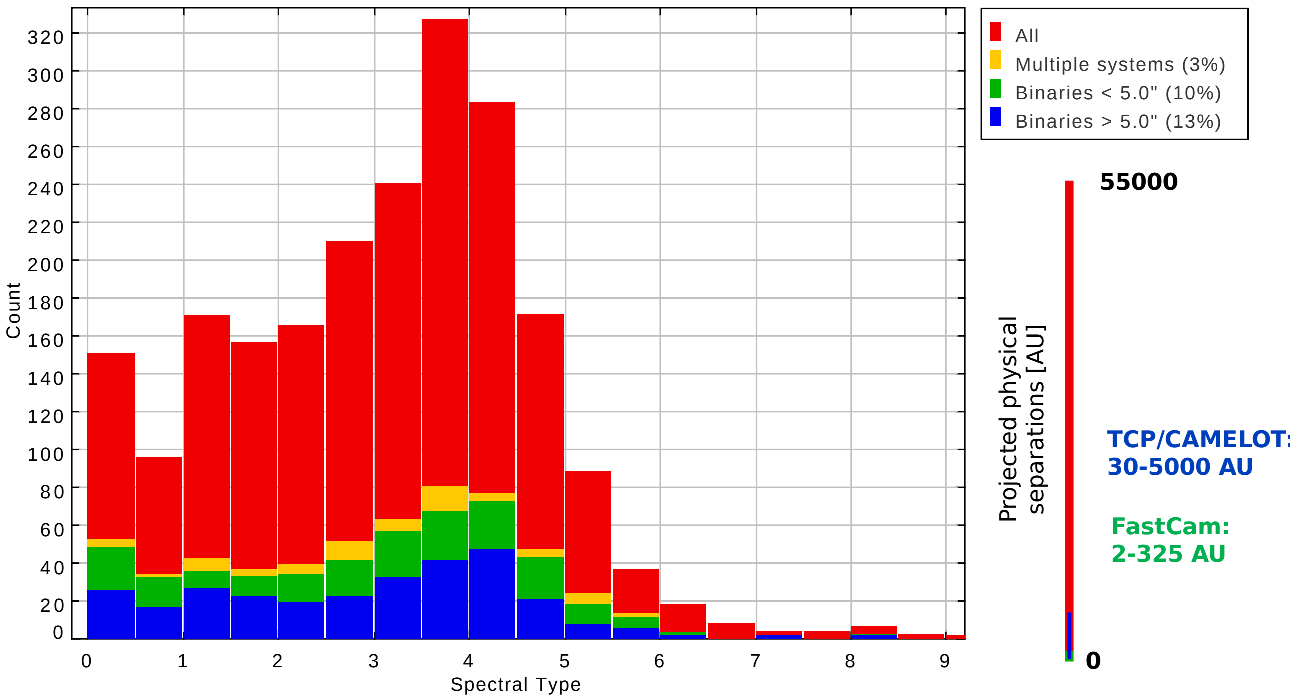

Figure .3: Spectral type distribution of close and wide binaries and multiple systems. The colored vertical bar to the right indicates the projected physical separations coverage of the instruments used in this study and of the sample.

4. The CARMENCITA sample

4.1 Multiplicity

Projected physical separations covered with FastCam, TCP and CAMELOT are in the range 2–5 000 au (Fig. .3). Accounting also for previously known pairs (Giclas et al. 1978; Luyten 1997; Beuzit et al. 2004), the total multiplicity fraction of the more than 2100 M dwarfs of CARMENCITA is 26 %, in agreement with given values in similar works (Janson et al. 2012, 2014; Jódar et al. 2012).

4.2 Parameters

For all multiples in CARMENCITA separated by over 5 arcsec, we measured angular separations. Closer angular separations were taken from the Washington Double Star catalogue or other sources. For those stars without parallax determination, we estimated spectro-photometric distances (d) from our own M_J-spectral type relation derived from 2MASS photometry, parallactic measurements from *Hipparcos* and spectral types determined mostly by Alonso-Floriano et al. in prep.

We computed projected physical separations (s) in the range from 0.5 to 55 000 au. Only 55 systems have $s < 10$ au and just seven have $s > 10\,000$ au. Masses (M_1, M_2) of the components were estimated with the NextGen models from Baraffe et al. 1998, assuming a typical age interval of $\tau \sim$ 1–5 Gyr. Gravitational potential energies (U_g^*) and periods (P)

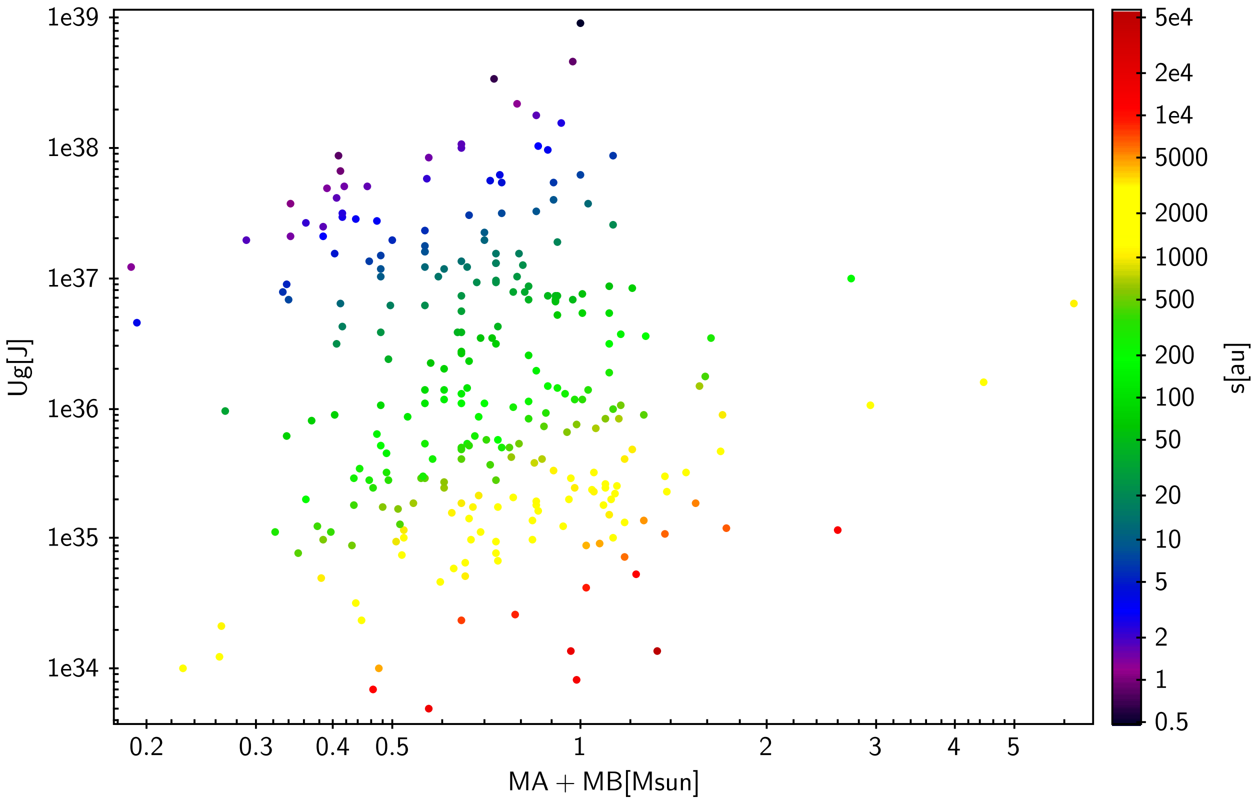

Figure .4: Binding energy vs. total mass in logarithmic scale of a representative sample of CARMENCITA M-dwarf multiple systems. There is a U_g^* threshold at -10^{33} J. The right color bar indicates projected physical separations, also in logarithmic scale.

were estimated from the total mass M_1+M_2 (Fig. .4). While there are no ultra-fragile systems in our sample (Caballero 2009; Dhital et al. 2012), there are however some interesting close pairs for which one could easily derive dynamical masses.

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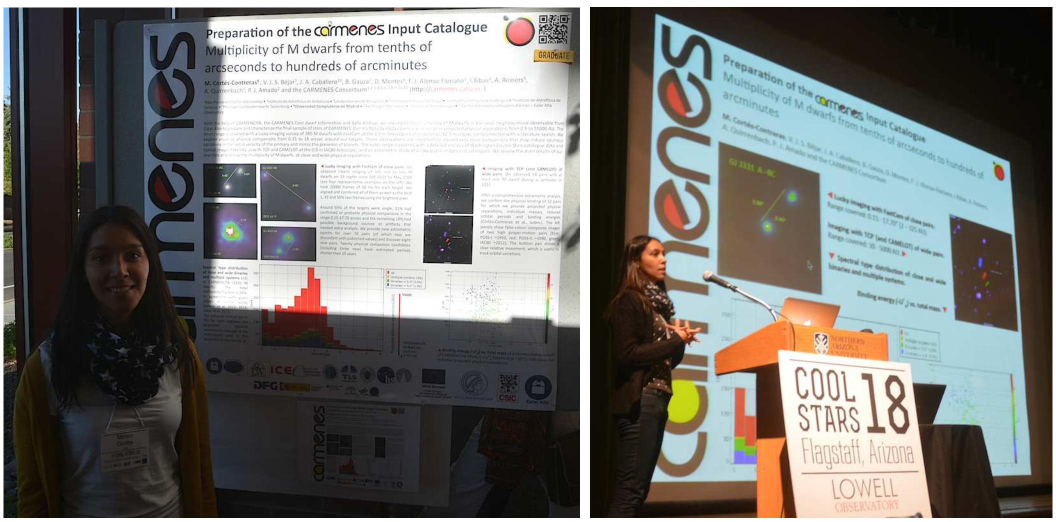

Miriam Cortés in front of her CARMENES poster during the CS18 meeting (left) and during the poster pop-up presentation of the splinter session: "Portraying The Hosts: Stellar Science From Planet Searcher" (right)