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The magnetically-active, low-mass, triple system GIC 158

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ABSTRACT

Aims. We investigated in detail the system GIC 158, whose primary is an active M4.5Ve star previously thought to be young ($\tau \sim$ 300–500 Ma).
Methods. We collected intermediate- and low-resolution optical spectra taken with 2 m-class telescopes, photometric data from the B to 8 μm bands, and eleven astrometric epochs with a time baseline of over 56 years for the two components in the system, G 125–15 and G 125–14.
Results. We derived M4.5V spectral types for the two stars, confirmed their common proper motion, estimated the heliocentric distance and projected physical separation, determined the galactocentric space velocities, and deduced a most-probable age older than 600 Ma. We discovered that the primary, G 125–15, is in turn an inflated, double-lined, spectroscopic binary with a short period of photometric variability of $P \sim 1.6$ d, which we associated to orbital synchronisation. The observed X-ray and Hα emissions, photometric variability, and abnormal radius and effective temperature of G 125–15 AB indicate strong magnetic activity, possibly due to fast rotation. Besides, the projected physical separation between G 125–15 AB and G 125–14 is $s = 1200^{+300}_{-200}$ AU, which makes GIC 158 to be one of the widest known low-mass systems.
Conclusions. G 125–15 AB is a nearby ($d \approx 26$ pc), bright ($J \approx 9.6$ mag), active binary with a single companion of the same spectral type at a wide separation. They are thus ideal targets for specific follow-ups to investigate wide and close multiplicity or stellar expansion and surface cooling due to reduced convective efficency.

Key words. stars: activity – binaries: visual – binaries: spectroscopic – stars: individual (G 125–14, G 125–15) – stars: low mass – stars: variables: general

1. Introduction

The binary GIC 158 (Washington Double Star identifier: WDS 19312+3607) is formed by the two nearby high proper-motion stars G 125–15 and G 125–14. According to Worley & Douglass (1997), the date of first satisfactory observation of GIC 158 was in 1961 by Giclas et al. (1971), who made the following note: *"These two stars form a common proper-motion pair with a separation of about 47 arcsec in PA [position angle] 346 deg"*. The primary, G 125–15, is an active M4.5Ve star with near-solar metal abundance based on spectroscopic narrow-band indices of titanium oxide and calcium hydride and the Hα index defined by the flux ratio $F_{6560-6566\,Å}/F_{6545-6555\,Å}$ (Reid et al. 2004). The secondary, G 125–14, is about 1 mag fainter in the visible and has never been investiagted spectroscopically.

Interestingly, the system GIC 158 might be a few hundred megayears old. First, Fuhrmeister & Schmitt (2003), using data from the *ROSAT* All-Sky Bright Source Catalogue (Voges et al. 1999), associated the soft X-ray source 1RXS J193113.0+360730 to G 125–15 (source count rate with the Position Sensitive Proportional Counter: $CR_{\rm 1RXS}$ = 153±19 ks^{-1}; total positional error: Δ = 7 arcsec). Secondly, Daemgen et al. (2007) and Allen & Reid (2008) inferred from its location in a $\log{(F_{\rm X}/F_J)}$ vs. $V - J$ diagram that G 125–15 has X-ray activity levels that exceed those of Pleiades stars of a similar spectral type. They conservatively assumed an age of 300–500 Ma, although the M dwarfs in their sample could be younger. Youth, closeness, and late spectral type are the optimal properties for the search for faint companions to stars, which made G 125–15 to be the target of adaptive optics and IRAC/*Spitzer* searches by Daemgen et al. (2007) and Allen & Reid (2008), respectively. They provided restrictive upper limits for the magnitudes and masses of hypothetical brown dwarf and planetary companions at *close* separations (up to a few arcseconds). The secondary star, G 125–14, fell out of the field of view of Altair+NIRI/Gemini North in Daemgen et al. (2007), but is among the brightest sources in the IRAC/*Spitzer* images in Allen & Reid (2008). Both groups unintentionally overlooked the existence of the binary. They did not take into

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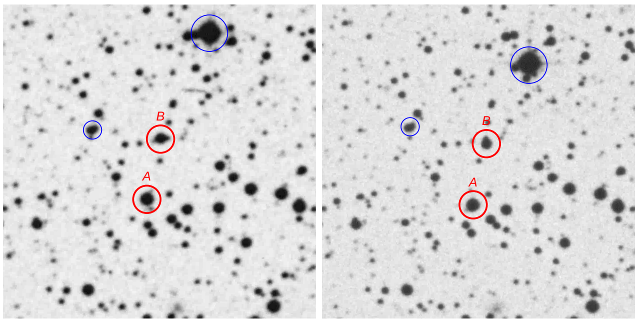

Fig. 1. Photographic R_F-band images centred on GIC 158. *Left:* epoch J1952.54 (DSS1). *Right:* epoch J1992.66 (DSS2). North is up, east is left. Approximate size is 4×4 arcmin^2. G 125–15 (*A*) and G 125-14 (*B*) are labelled and marked with thick (red) circles. The brightest star in the field of view is the high proper-motion star BD+35 3659, marked with a big thin (blue) circle. There is a second proper-motion binary in the field, at about 1.2 arcmin to the northeast of G 125–15, marked with a small thin (blue) circle. Its approximate coordinates, proper motion, and angular separation are: 19 31 16.6 +36 08 27 J2000, $(\mu_\alpha \cos\delta, \mu_\delta) \approx (+22, +54)$ mas a^{-1}, and $\rho \approx 3.5$ arcsec.

account the photometric variability of the primary either, which might be related to activity (and in turn to youth). During the Hungarian-made Automated Telescope Network (HATnet) variability survey in a field chosen to overlap with the *Kepler* mission, Hartman et al. (2004) found G 125–15 to be a periodic variable with a pulsating variable-like light curve. They measured a period $P_{\rm phot}$ = 1.6267 d and an amplitude ΔI = 0.097 mag. The secondary star, G 125–14, was not analysed.

We serendipitously recovered the binary during a virtual observatory search for companions to high-proper motion Luyten stars carried out at the Observatori Astronòmic del Garraf[1] (Caballero et al. 2008b). Further details on this search will be provided in a forthcoming paper. GIC 158 fell at a couple arcminutes to the south-southeast of one of our programme stars, BD+35 3659 (NLTT 47900; see Fig. 1).

From the approximate angular separation of 47 arcsec between G 125–15 and G 125–14 and preliminar estimates of the heliocentric distance to the primary based on spectroscopic parallax ($d \sim 15$ pc – Reid et al. 2004; Allen & Reid 2008), we derived a rough projected physical separation $s \sim 700$ AU. This wide separation and the late spectral type of the primary would make the system to be one of the widest low-mass binaries in the field (Caballero 2007a; Artigau et al. 2007; Radigan et al. 2009). If the age estimation by Daemgen et al. (2007) and Allen & Reid (2008) were correct, the GIC 158 system would besides be the first *young* wide low-mass binary in the solar neighbourhood. Thus, we aimed at characterising in detail this system with new observations and data compilations from the literature.

2. Observations and analysis

Our first purpose was to confirm the common proper motion of G 125–15 and G 125–14, which had never been done. We compiled astrometric data of both stars at three different epochs

Table 1. Multi-epoch astrometric measurements of GIC 158.

Epoch	ρ [arcsec]	θ [deg]	Source
1952 Jul 17	45.5±0.4	348	POSS-I Red
1988 Jun 13	46.2±0.4	347	POSS-II Blue
1992 Aug 31	46.0±0.4	348	POSS-II Red
1993 Jun 13	45.7±0.4	347	POSS-II Infrared
1994 Aug 20	45.82±0.10	347.3	SDSS
1998 Jun 01	45.80±0.12	347.4	2MASS
2001 Aug 26	45.90±0.06	347.5	CMC14
2004 Oct 30	45.81±0.10	347.4	IRAC/*Spitzer*
2008 Mar 07	45.82±0.15	347.3	Tacande
2008 May 05	45.70±0.15	347.4	2.2 m CAHA
2008 Oct 23	45.80±0.15	347.3	Tacande

from the Two-Micron All-Sky Survey (2MASS – Skrutskie et al. 2006), Sloan Digital Sky Survey (SDSS DR7 – Abazajian et al. 2009), and Carlsberg Meridian Catalog 14 (CMC14 – Muiños 2006). We used the SuperCOSMOS (Hambly et al. 2001) digitisations of the First (1948–1958) and Second (1985–2000) Palomar Observatory Sky Survey (POSS-I and POSS-II Blue, Red, and Infrared) for obtaining earlier astrometric epochs. The IRAC/*Spitzer* images taken by Allen & Reid (2008) gave us an extra epoch.

We used the 0.4 m Telescopio del Observatorio de Tacande (Tacande)[2] in La Palma, Spain, and the 2.2 m Calar Alto Teleskop (2.2 m CAHA) in Almería, Spain, for acquiring three additional astrometric epochs. Tacande is a catadioptric telescope Cassegrain relay of 0.4 m diameter at $f/65$ equipped with a dual CCD camera SBIG ST-8XME. At 2.2 m CAHA, we used the CAFOS[3] instrument with the Site#1d_15 detector. We performed the astrometric calibration of the Tacande and 2.2 m CAHA images, which were taken with the most suitable filters and exposure times, using a reference grid of 2MASS sources with null USNO-B1 (Monet et al. 2003) proper motions and the IRAF `geomap` and `geoxytran` tasks within the `immatch` package. Dates, angular separations, position angles, and sources of the 11 astrometric epochs are listed in Table 1. The main contributors to the errors in angular separation come from the poor fitting of the point spread function in the POSS digitisations (because of the brightness and *saturation* of G 125–15 and G 125–14) and the astrometric calibrations in our Tacande and 2.2 m CAHA images. All the measurements are consistent within 1σ with mean angular separation $\overline{\rho}$ = 45.83±0.17 arcsec and position angle $\overline{\theta}$ = 347.5±0.4 deg. For comparison, during the 56.271 years of our time baseline, the two stars traveled together about 10.3 arcsec.

Using the astrometric epochs in Table 1 and the methodology exposed in Caballero (2010), we also determined the proper motion of the primary at $(\mu_\alpha \cos\delta, \mu_\delta)$ = (–116.3±2.0, –100.6±1.2) mas a^{-1}, which supersedes previous determinations with larger uncertainties (Luyten 1979; Salim & Gould 2003; Hanson et al. 2004; Lépine & Shara 2005; Ivanov 2008).

[1] `http://www.oagarraf.net/.`

[2] `http://www.astropalma.com/astropalma_eng.htm.`

[3] `http://www.caha.es/alises/cafos/cafos.html.`

Table 2. Basic data of G 125–15 AB and G 125–14.

	G 125–15 AB	G 125–14
α^{J2000}	19 31 12.57	19 31 11.75
δ^{J2000}	+36 07 30.1	+36 08 14.8
u [mag]	17.094±0.009	18.598±0.020
B [mag]	15.61±0.05	16.58±0.06
g [mag]	15.075±0.003	16.072±0.003
V [mag]	14.12±0.09	15.16±0.10
r [mag]	14.148±0.010	14.690±0.003
R [mag]	12.60±0.06	13.71±0.06
i [mag]	...	13.852±0.010
I [mag]	11.02±0.05	12.30±0.05
z [mag]	...	13.327±0.003
J [mag]	9.609±0.022	10.924±0.022
H [mag]	9.061±0.020	10.408±0.020
K_s [mag]	8.839±0.019	10.137±0.019
[3.6] [mag]	8.9±0.2	10.0±0.2
[4.5] [mag]	8.59±0.01	9.90±0.05
[5.8] [mag]	8.45±0.01	9.79±0.05
[8.0] [mag]	8.39±0.01	9.71±0.05
Sp. type	M4.5±0.5Ve	M4.5±0.5V
V_r [km s^{-1}]	–43±5 / –3±5	–26±2
pEW(Hα) [Å]	–5.8±0.7	< +0.13
pEW(Li I) [Å]	< +0.13	< +0.13
M_J [mag]	$7.5^{+0.5}_{-0.4}$	$8.8^{+0.5}_{-0.4}$
$\mathcal{M}$ [$M_\odot$]	0.18±0.05 / 0.18±0.05	0.18±0.04

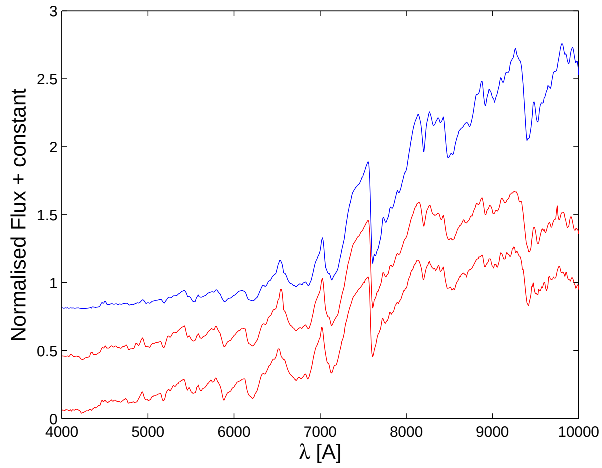

Fig. 2. CAFOS/2.2 m CAHA spectra of FL Vir AB (in blue), G 125–15, and G 125–14 (in red), from top to bottom. They are normalised at 7500 Å and conveniently shifted in the vertical direction.

Next, we compiled *BVRI*, *ugriz*, *JHK*$_s$, and [3.6][4.5][5.8][8.0] photometry of G 125–15 and G 125–14. We list the measured values and corresponding uncertainties in Table 2. CAFOS images in the *BVRI* bands were calibrated using stars in common with a number of overlapping optical catalogues (*B*, *V*: Tycho-2 –Høg et al. 2000– transformed into the Johnson system; *R*: Weis 1996 –plus a 0.40 mag correction–; *I*: Hartman et al. 2004). We retrieved *ugriz* and *JHK*$_s$ magnitudes and coordinates from the SDSS and 2MASS catalogues, respectively (the SDSS *iz* magnitudes of G 125–15 were affected by saturation). The magnitudes of G 125–15 in the four IRAC/*Spitzer* channels were taken from Allen & Reid (2008), while those of G 125–14 were measured by us after downloading the public IRAC post-calibrated images.

On 2008 May 05, we also used CAFOS with the grism Blue–400 for taking low-resolution optical spectra (R ~ 200 at Hα λ6562.8 Å) of both G 125–15 and G 125–14. The two stars felt simultaneously in the long slit (i.e., we did not observe in parallactic angle). We also observed the late-type dwarf FL Vir AB (M5.5Ve; Joy 1947) and the spectrophotometric standard star HZ 44. We carried out the bias correction, flat-fielding, spectra extraction, wavelength calibration, and instrumental response correction following standard procedures within the astronomical data reduction package REDUCEME (Cardiel 1999)[4]. Useful wavelength coverage was from 4 000 to 10 000 Å. The final CAFOS spectra of G 125–15, G 125–14, and FL Vir AB are shown in Fig. 2. From our data and classification based on pseudo-continuum indices (e.g., Martín et al. 1999), we agreed with the spectral type determination of the primary at M4.5Ve by Reid et al. (2004). The spectral types of G 125–15 and G 125–14 are identical within an uncertainty of 0.5 dex (Table 2).

Two new spectra were taken on 2009 Sep 09 with the Intermediate Dispersion Spectrograph (IDS)[5] at the 2.5 m Isaac Newton Telescope (INT) on the Observatorio del Roque de los Muchachos, La Palma, Spain. In this case, we used the H1800V grating and the 0.95 arcsec slit, which provided a spectral resolution power of R ~ 9200, and observed in parallactic angle. With the same configuration, we also obtained spectra of the comparison stars GJ 687 (M3.5V) and GJ 1227 (M4.5V) and a number of radial-velocity standards. The reduction and analysis of the data were carried out using common tasks within the IRAF envirnonment. A part of the spectra of G 125–15, G 125–14, and GJ 1227 around the Hα region is shown in Fig. 3.

The Hα line in the intermediate-resolution spectrum of G 125–15 was in apparent, symmetric emission. We measured a pseudo-equivalent width of pEW(Hα) = –5.8±0.7 Å. The line width at 10 % height was 3.0 Å, significantly larger than those of arc lines or of Hα emission lines in some active late-type stars observed during the run with the same instrumental configuration (of about 1.5 Å; Klutsch et al., in prep.). Remarkably, the absorption lines of G 125–15 appeared double, which implies that the star is in turn a spectroscopic binary (SB2). The apparent broadening of the Hα line is more likely associated to the partial overlapping of two non-broadened emission lines, one redshifted and other blueshifted, than to a process of accretion from a circumstellar disc, such as those found in classical T Tauri stars. The consequences of the spectroscopic binarity of G 125–15 are discussed in Section 3. Besides this, we imposed a restrictive upper limit to the pseudo-equivalent width of the Li I λ6707.8 Å line. This is not surprising, since M dwarfs destroy its lithium content in 20–150 Ma. Similar upper limits

[4] http://www.ucm.es/info/Astrof/software/reduceme/reduceme.html.

[5] http://www.ing.iac.es/Astronomy/instruments/ids/.

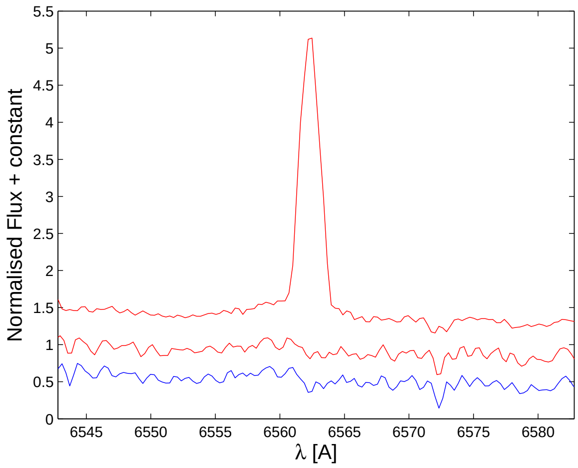

Fig. 3. A 40 Å-wide region around the Hα wavelength of the IDS/INT spectra of G 125–15, G 125–14 (in red), and GJ 1227 (in blue), from top to bottom. They are normalised at 6550 Å and conveniently shifted in the vertical direction. Note the double lines in the spectra of G 125–15 and the resemblance between the spectra of G 125–14 and GJ 1227.

were established for the Hα and Li I lines in G 125–14 (the Hα line of the secondary is filled or in very faint absorption). The results are summarised in Table 2.

Finally, we determined the radial heliocentric velocity of the *three* components in GIC 158. During the computation, we analysed the cross-correlation functions between the IDS/INT spectra of G 125–15 (hereafter G 125–15 AB), G 125–14, the comparison stars, and radial-velocity standard stars in our run with the latest spectral types (about K7V). We found that the cross-correlation function of G 125–15 AB compared to any other single star observed with IDS had always two peaks, which agrees with the double-lined spectrum of the primary and, hence, its spectroscopic binarity.

While we could measure a radial velocity for G 125–14 with a reasonable precision of 2 km s^{-1} (Table 2), the binarity of G 125–15 AB and the proximity between the two peaks in their cross-correlation functions allowed us to determine the radial velocities of G 125–15 A and B with a precision about three times lower. The difference in radial velocity between A and B was of 40 km s^{-1} and the mean (i.e., the radial velocity of the centre of mass of A and B) was consistent with the radial velocity of G 125–14 within uncertainties. In practice, we were not able to differentiate between the components G 125–15 A and B because of the resemblance between depths of the double lines in the spectrum and heights of the two peaks in the cross-correlation functions. As a result, we assumed that A and B have the same basic parameters (e.g., mass, radius, effective temperature, magnitude, Hα emission).

3. Discussion

3.1. Heliocentric distance

Allen & Reid (2008) derived $d = 15.3^{+1.9}_{-1.6}$ pc to G 125–15 AB assuming singleness and normal radius and effective temperature (Reid et al. 2004 had derived d = 11.0±0.9 pc to G 125–15 AB, but also $d = 85^{+17}_{-15}$ pc to G 125–14 based on an incorrect V magnitude). This would lead to a projected physical separation between G 125–15 AB and G 125–14 of $s = 700^{+90}_{-70}$ AU.

Table 3. Properties of the GIC 158 system.

Quantity	Value	Unit
ρ	45.83±0.17	arcsec
	0.764±0.003	arcmin
θ	347.5±0.4	deg
d	26^{+6}_{-5}	pc
$\mu_\alpha \cos\delta$	–116.3±2.0	mas a^{-1}
μ_δ	–100.6±1.2	mas a^{-1}
V_r	–26±2	km s^{-1}
U	+7±4	km s^{-1}
V	–31±2	km s^{-1}
W	+3±2	km s^{-1}
s	1200^{+300}_{-200}	AU
τ	0.6–5	10^9 a
$\mathcal{M}_{\rm total}$	0.54±0.08	$M_\odot$
U_g	–10±2	10^{34} J
P	57	10^3 a

There are numerous absolute magnitude-spectral type relations useful for determining heliocentric distances of intermediate- and late-M field dwarfs without parallax measurement (e.g., Henry et al. 1994; Hawley et al. 2002; Cruz et al. 2003; Phan-Bao & Bessell 2006; Caballero et al. 2008a). In this work, we used the M_J-Sp. type relation from Scholz et al. (2005), which is given in spectral type intervals spaced by 0.5 dex. The derived absolute magnitude of G 125–14 was $7.5^{+0.3}_{-0.4}$ mag. For the computation, we could use only the secondary G 125–14 because the absolute magnitude of the primary G 125–15 AB is affected by spectroscopic binary and activity (see Section 3.2). Using the value of M_J, the 2MASS J-band magnitude of G 125–14 in Table 2, and the Pogson law, $J - M_J = 5 \log d - 5$, we estimated a heliocentric distance of $d = 26^{+6}_{-5}$ pc. At this distance, the angular separation between G 125–15 AB and G 125–14 translates into a projected physical separation of $s = 1200^{+300}_{-200}$ AU.

3.2. Close binarity and magnetic activity

From Table 2, the primary is 1.0–1.5 mag brighter than the secondary depending on the passband, while they have the same spectral type within a 0.5 dex uncertainty. The equal-mass binarity of the primary accounts for only about 0.75 mag (2.5 log 2). Since the stars are located at the same heliocentric distance and there is no obstacle in the line of sight (e.g., an absorbing circumstellar disc), the primary displays a wavelength-dependent overbrightness of 0.3–0.8 mag (if G 125–15 consisted of three identical M4.5V stars, there would be a constant 1.2 mag overbrightness). Besides, G 125–15 AB is *redder* than G 125–14. For example, the difference in $r - J$ colours, which are indicative of effective temperature, is $\Delta(r - J)$ = 0.77±0.03 mag. This deviation is marginally consistent within the 0.5 dex uncertainty in spectral type determination, but not with the observed overbrightness of 0.3–0.8 mag.

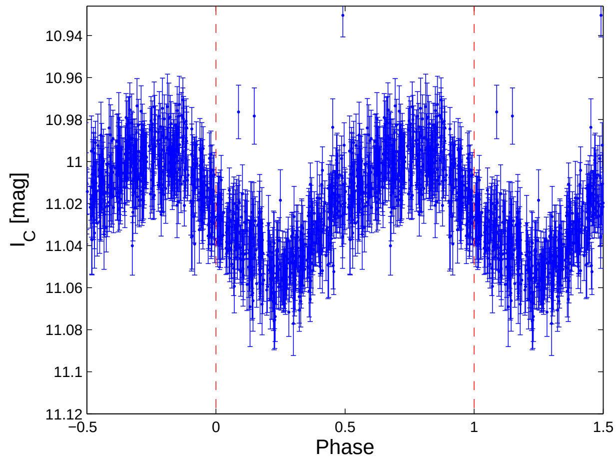

Fig. 4. I_c-band light curve of G 125–15 AB from HATnet data in Hartman et al. (2004). The light curve is folded to the period $P_{\rm phot}$ = 1.6267 d. Note the sudden brightenings at approximate phases 0.1–0.2 and 0.5.

We estimated the ratios of effective temperature and radius needed to explain the observed magnitude and colour differences between G 125–15 AB and G 125–14. The ratio of the sum of observed fluxes at the B to [8.0] bands is $\sum \lambda F_{\lambda,(1)} / \sum \lambda F_{\lambda,(2)} \sim 3.2$ (using $\sum \lambda F_\lambda = \sum \frac{c}{\lambda} F_{\nu 0} 10^{-\frac{m_\lambda}{2.5}}$ and the corresponding zero-point conversion factors[6]), where '(1)' and '(2)' indicate G 125–15 AB and G 125–14, respectively. This quotient is a reasonable approximation to the ratio of total luminosities, $L_{(1)}/L_{(2)}$, from where one derives $2(R_{(1)}/R_{(2)})^2 (T_{\rm eff,(1)}/T_{\rm eff,(2)})^4 \sim 3.2$ after assuming that the two components in G 125–15 AB have the same mass and effective temperature. A cooler effective temperature, shown by a redder $r - J$ colour, must be counterbalanced by a larger radius. We estimated that the two components in G 125–15 AB are $\Delta T_{\rm eff} \lesssim 5$ % cooler and $\Delta R \lesssim 30$ % larger than normal M4.5 dwarfs (including G 125–14), which have $T_{\rm eff} \sim 2900$–3300 K and $R \sim 0.23$–$0.26\,R_\odot$. Effective temperature variations larger than 5 % would lead to a different spectral type classification of G 125–15 AB and G 125–14.

Radii and effective temperatures in M dwarfs are affected by activity levels (Stauffer & Hartmann 1986; Mullan & MacDonald 2001; Torres & Ribas 2002; López-Morales 2007; Reiners et al. 2007; Morales et al. 2008). According to Chabrier et al. (2007), reduced heat fluxes and, thus, larger radii and cooler effective temperatures in active low mass stars and brown dwarfs than in regular (inactive) ones are due to "reduced convective efficiency, due to fast rotation and large field strengths, and/or to magnetic spot coverage of the radiating surface". Previously, the activity scenario of G 125–15 AB was only sustained by the large relative X-ray flux (Daemgen et al. 2007; Allen & Reid 2008). Now, we back it by its Hα emission (Reid et al. 2004; this work), stellar expansion (by about 30 %; this work), and photometric variability (Hartman et al. 2004). The folded light curve of G 125–15 AB shown in Fig. 4 is more easily explained by an asymmetrical distribuiton of cool spots concentrated in certain hemispheres of two close, magnetically-active, orbital-locked, M4.5Ve stars rather than by pulsations in a low-mass dwarf. The period observed by Hartman et al. (2004) would be the rotational period of the system at $P_{\rm phot} \sim 1.6$ d. This value is quite short for field M dwarfs and indicative of fast rotation, as expected from the Chabrier et al. (2007) scenario. Furthermore, the three outlier datapoints in Fig. 4 (sudden brightenings) could be short-duration flares, which are frequent in active M dwarfs.

[6] `http://nsted.ipac.caltech.edu/NStED/docs/parhelp/Photometry.html`.

3.3. Space motion, age, mass, and semimajor axis

We considered that the strong magnetic activity in G 125–15 AB is not due to youth, as previously reckoned, but to fast rotation in a close orbital-locked system. First, if it were young, G 125-14 should also display signposts of youth. Second, we derived the galactocentric space velocities UVW of the GIC 158 system (Table 3) as in Montes et al. (2001). In the UV and WU diagrams, GIC 158 lies outside the region that includes young moving groups with ages from $\tau \ll 100$ Ma (e.g., TW Hydra, β Pictoris, AB Doradus) to $\tau \sim 300$–600 Ma (e.g., Castor, Hyades). However, the UVW velocities of GIC 158 are very different from those of old-disc stars (Legget 1992). The most probable age of G 125–15 AB and G 125–14 from kinematics criteria is thus $\tau \sim 0.6$–5 Ga.

We estimated the semimajor axis of the close binary G 125–15 AB assuming that the orbital period coincides with the photometric one. Before applying the third Kepler's law, we had to estimate the masses of each component in the system from their absolute magnitudes and theoretical models. We determined the mass of G 125–14, the only normal single dwarf in the system, at about $0.18\,M_\odot$ using its M_J magnitude (Table 3) and NextGen theoretical isochrones (Baraffe et al. 1998), which are little sensitive to age if $0.3\,{\rm Ga} < \tau < 10\,{\rm Ga}$. Based on the resemblance of spectral types, we cautiously assigned similar masses to the components in G 125–15 AB. Using these masses and the rotational-orbital period of the system, we estimated that the two stars are separated by only 0.019±0.002 AU ($4.0 \pm 0.5\,R_\odot$ or about 10–20 stellar radii).

The estimated semimajor axis a is very short for M dwarfs and comparable to that of the well-known CM Dra system, which is formed by two population II M4.5 dwarfs (Lacy 1977; Vilhu et al. 1989; Chabrier & Baraffe 1995; Metcalfe et al. 1996; Viti et al. 1997; Doyle et al. 2000; Morales et al. 2009). The two flaring stars in CM Dra are separated by 0.0175±0.0004 AU and have a rapid tidally-synchronised rotation period of 1.27 d, slightly shorter than the photometric period of G 125–15 AB. Because of its high inclination angle of i = 89.82 deg, CM Dra is an eclipsing binary. In analogy, the probability of eclipsing in G 125–15 AB must be relatively high, of about 10–20 % (estimated from the ratio $R_\star/a$, where $R_\star$ is the radius of the two components). If the individual masses in G 125–15 AB were lower than expected for its spectral type due to activity (as seen in CM Dra – Lacy 1977), the semimajor axis would be shorter than 0.019 AU and the probability of eclipsing would increase.

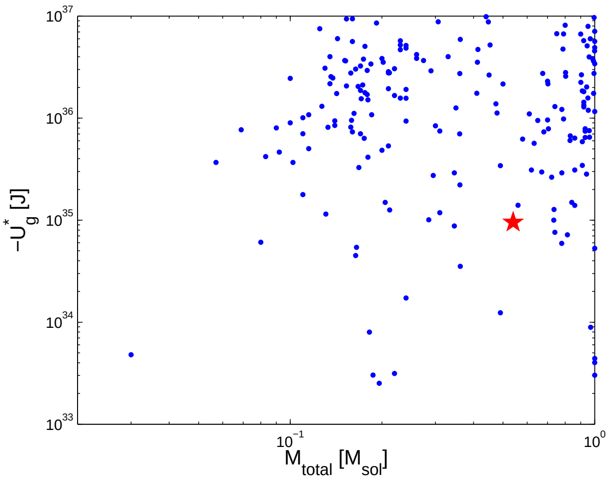

Fig. 5. Binding energy as a function of total mass for the sample of systems with low-mass components in Caballero (2009). GIC 158 is indicated by a (red) filled star.

Radii, masses, and effective temperatures of the two components in CM Dra, as well as in other ecplipsing binaries, are widely used to compare observations to theoretical models. On the contrary to CM Dra, which has a white-dwarf proper-motion companion at 26 arcsec, G 125–15 AB has a wide proper-motion companion, G 125–14, that is a dwarf of the same spectral type within an uncertainty of 0.5 dex. The *three* stars can be used properly to study the relation of stellar radius and effective temperature with activity at the bottom of the main sequence. Besides, as discussed in Section 3.2, G 125–15 AB and G 125–14 show a temperature reversal with a relative amplitude of $\lesssim 5$ %. Such temperature reversals have been also detected in other cornerstone active M-type eclipsing binaries, like the young brown-dwarf pair 2MASS J05352184–0546085 (Stassun et al. 2006, 2007).

3.4. Wide binarity and binding energy

Table 3 summarises the properties of the wide pair mentioned above and others such as the orbital period, P (from Kepler's third law), and gravitational binding energy, $U_g = -G\mathcal{M}_{(1)}\mathcal{M}_{(2)}/r \approx -G\mathcal{M}_{(1)}\mathcal{M}_{(2)}/s$ (where $\mathcal{M}_{(1)}$ is the combined mass of G 125–15 A and B and r is the actual physical separation to G 125–14). If the system were younger than 300 Ma, as previously suggested, GIC 158 would be intrinsically brighter and, thus, further, wider, less massive, and less bound.

Even accounting for the largest possible uncertainties in heliocentric distance, activity, multiplicity, and system age, GIC 158 is among the widest *low-mass* "binaries" known (Table 4). Besides, it is the first example of a new class of systems with projected physical separations wider than 1000 AU and with masses intermediate between those of Koenigstuhl 1-like (2M0126–50 AB, Koenigstuhl 1 AB, and 2M1258+40 AB; faint binaries with total masses $\mathcal{M}_{total} < 0.2\,M_\odot$ and mass ratios $q \sim 1.0$) and ϵ Ind-like systems (G 124–62 ABC, ϵ Ind ABC, and GJ 618.1 AB; late-K- or early-M-type dwarfs with L- or T-type companions and mass ratios $q \sim 0.1$). In spite of its wide separation, there is a number of systems with lower binding energies than GIC 158 (e.g., Caballero 2009). In any case, it is one of the brightest, closest, low-mass systems with very low binding energies.

4. Summary

Daemgen et al. (2007) and Allen & Reid (2008) proposed that G 152–15 is a single, active, M4.5Ve-type star in the solar neighbourhood younger than the Hyades ($\tau < 600$ Ma) based mainly on strong X-ray activity detected by Fuhrmeister & Schmitt (2003). Actually, the dwarf is part of the wide binary system candidate GIC 158, which was tabulated earlier by Giclas et al. (1971). The proper-motion companion candidate is G 152–14, a poorly-known late-type dwarf more than 1.0 mag fainter located at about 46 arcsec to the north. To test the youth and wide-binarity hypotheses, we collected:

- intermediate-resolution (R ∼ 9200) optical spectroscopy with IDS at the 2.5 m Isaac Newton Telescope,
- low-resolution (R ∼ 200) optical spectroscopy, multi-wavelength photometry at the *BVRI* bands, and one astrometric epoch with CAFOS at the 2.2 m Calar Alto telescope,
- two astrometric epochs with the 0.4 m telescope at the Observatorio de Tacande,
- *ugriz*, JHK_s, and [3.6][4.5][5.8][8.0] photometry and three astrometric epochs from SDSS, 2MASS, and IRAC/*Spitzer* archive images,
- five additional astrometric epochs from CMC14 and SuperCOSMOS digitisations of POSS plates,
- and an I_C-band light curve from public HATnet data.

With all this information, we accomplished the following:

- confirming the common proper motion of G 152–15 (the primary) and G 152–14 (the secondary),
- measuring the proper motion of the system with an accuracy of 2 mas a^{-1},
- estimating the luminosity ratio of the primary and secondary,
- determining the spectral type of the two of them at M4.5V,
- measuring the Hα line in broad emission and detecting double absoprtion lines in the intermediate-resolution spectrum of the primary, which are indicative of spectroscopic binarity,
- computing the radial velocity of the two components in the primary and of the single secondary.

We concluded that G 152–15 AB and G 152–14 are 0.6–5 Ga old and form a hierarchical triple system at about 26 pc from the Sun. The three components have estimated masses of 0.18 $M_\odot$. While G 152–15 AB and G 152–14 are separated by $\rho = 45.83 \pm 0.17$ arcsec, which translates into a wide projected physical separation of 1200^{+300}_{-200} AU, G 152–15 A and B are separated only by about 0.02 AU. This close separation is responsible of the synchronisation of the pair and, thus, a fast rotational period identical to the observed photometric period of $P_{phot} = 1.6267$ d. Fast rotation accounts for the increased

Table 4. The widest systems in the field with total mass $\mathcal{M}_{\rm total} \leq 1\, M_\odot$ (GIC 158 is marked in italics).

Primary	Secondary	$\mathcal{M}_1$ [$M_\odot$]	$\mathcal{M}_2$ [$M_\odot$]	s [AU]	References
2M1258+40 A	2M1258+40 B	0.105	0.091	6700	Radigan et al. 2009
2M0126–50 A	2M0126–50 B	0.095	0.092	5100	Artigau et al. 2007, 2009
Koenigstuhl 1 A	Koenigstuhl 1 B	0.103	0.079	1800	Caballero 2007a, 2007b
G 124–62 A	G 124–62 BC	0.59	0.072+0.072	1500	Seifahrt et al. 2005
ϵ Ind A	ϵ Ind BC	0.71	0.042+0.027	1460	Scholz et al. 2003
G 125–15 AB	*G 125–14*	*0.180+0.180*	*0.180*	*1200*	*Giclas et al. 1971, this work*
GJ 618.1 A	G 618.1 B	0.67	0.070	1090	Wilson et al. 2001

magnetic activity of the pair, which is evidenced by the strong X-ray activity, Hα emission, photometric variability (possibly associated to the presence of cool spots), and, especially, larger radii of the two components with respect to normal dwarfs of the same spectral type. Besides, the wide separation between G 152–15 AB and G 152–14 and the mass ratio of $q \sim 0.5$ put GIC 158 in a new class of very wide ($s > 1000$ AU) systems intermediate between those that resemble Koenigstuhl 1 ($\mathcal{M}_{\rm total} \lesssim 0.2\, M_\odot$, $q \sim 1.0$) and ϵ Ind ($\mathcal{M}_{\rm total} \lesssim 1.0\, M_\odot$, $q \sim 0.1$).

The brightness and proximity of GIC 158 will facilitate further astrometric, photometric, and spectroscopic follow-ups, especially aimed at determining accurate trigonometric parallax, age, and radial and rotational velocities of the system, and investigating the relation between radius, effective temperature, and magnetic activity.

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