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# The brown dwarf candidate [KG2001] 102 in the Cha I cloud: Is it a multiple system?

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**Abstract.** We present deep $IJHK_s$ and $H_2$ images of a region in the Chamaeleon I dark cloud containing the very low-mass young object [KG2001]102, in an attempt to search for multiplicity and molecular outflows in the vicinity of this object. No low-velocity shocked structures were detected on our $H_2$ image. The broad-band and narrow-band images show that [KG2001]102 is composed of four objects within a radius of $\sim 2''$. The brightest component [KG2001]102 A shows near-IR excess emission and its mass is estimated to be in the range 33 to 55 $M_{\rm Jup}$. Red spectra were obtained of the two fainter components B and C. The spectrum of the former suggests a K7V spectral type while the spectrum of component C is too noisy to allow a reliable classification but rules out a late M-type. The three faint components (B, C and D) have $IJHK$ colors that suggest a much later spectral type, with extinctions similar to other members of the cloud. The computed probability of finding randomly a pair of field stars like [KG2001]102 AB is $1.5 \times 10^{-3}$ while for a triple optical system like [KG2001]102 ABC, it would be $3.8 \times 10^{-5}$ and more than an order of magnitude lower for finding a quadruple system like this by chance projection.

**Key words.** Brown dwarfs

## 1. Introduction

Here, we report the results of deep and high spatial resolution near-infrared images of an area towards the nearby dark cloud and star formation region Chamaeleon I, at a distance of 160 pc. The observed region contains the candidate sub-stellar object [KG2001]102. This source shows conspicuous H$\alpha$ line emission in its spectrum (Saffe et al.2003), confirming its membership of the dark cloud. [KG2001]102 was discovered recently by Kenyon & Gómez (2001) during a near-IR survey of the Chamaeleon I (Cha I) cloud and appears to be a multiple system.

## 2. Observations and data reduction

We obtained deep and high spatial resolution broad-band $JHK_s$ images complemented with an $H_2$ narrow-band image ($\lambda_\circ$= 2.149 $\mu$m; $\Delta\lambda$=0.0224 $\mu$m) of a region of the Chamaeleon I dark cloud that contains the candidate

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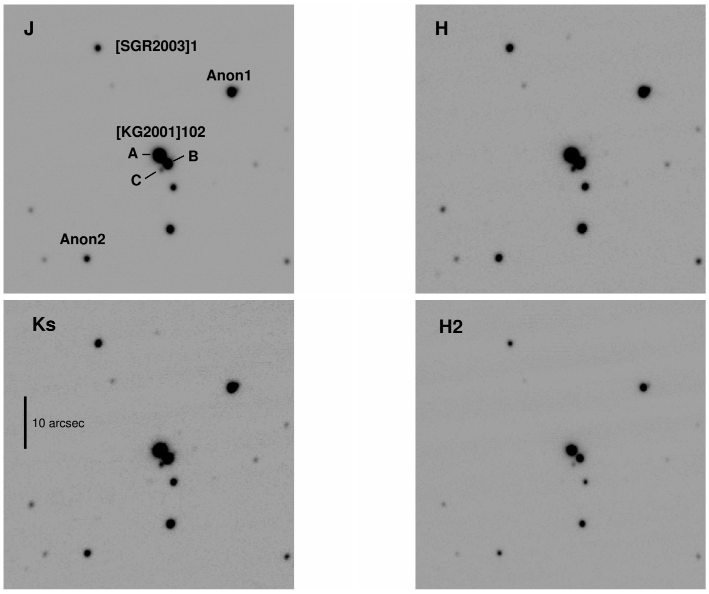


**Fig. 1.** $JHK_s$ and $H_2$ images centered at $\alpha = 11^h\ 09^m\ 49\overset{s}{.}5$; $\delta = -77°\ 31'\ 20''$ (J2000) containing [KG2001]102 and in Cha I. North is up and east is to the left.

**Table 1.** Positions and near-IR photometry of the stellar sources

| Source | $\alpha(J2000)$ | $\delta(J2000)$ | $I$ | $J$ | $H$ | $K_s$ |
|---|---|---|---|---|---|---|
| | h m s | ° ′ ″ | mag. | mag. | mag. | mag. |
| [SGR2003]1 | 11 09 52.79 | -77 30 59.7 | 18.79 | 16.29 | 15.37 | 14.98 |
| [KG2001]102 A | 11 09 49.12 | -77 31 20.5 | 16.14 | 13.09 | 12.46 | 11.86 |
| [KG2001]102 B | 11 09 48.63 | -77 31 22.1 | 16.62 | 14.47 | 13.69 | 13.36 |
| [KG2001]102 C | 11 09 49.00 | -77 31 23.1 | 19.82 | 17.60 | 16.67 | 16.29 |
| [KG2001]102 D | 11 09 48.36 | -77 31 21.0 | 21.4 | 18.8 | 17.9 | 17.4: |
| Anon1 | 11 09 44.9 | -77 31 07 | 16.74 | 14.66 | 13.89 | 13.40 |
| com-Anon1 | 11 09 44.6 | -77 31 06 | 20.7 | 18.3 | 17.5 | 17.0 |
| Anon2 | 11 09 53.3 | -77 31 40 | 18.59 | 16.34 | 15.53 | 15.37 |

YBD [KG2001]102. The observations were made on the night of 17 May 2003 using the near-infrared camera PANIC attached to the Magellan-Clay 6.5m telescope at Las Campanas Observatory (Chile). Fig. 1 shows a portion of the calibrated $JHK_s$ and $H_2$ images covering a $55'' \times 55''$ field centered on [KG2001]102. This object appears in all bands as multiple, with three close but well separated stellar components. We named these A, B, and C, as labelled on the $J$ image presented in Fig. 1. A faint close fourth component (D) was also found after detailed analysis of the images. Two uncalibrated direct CCD $I$-band images of the same region were obtained with IMACS in its direct imaging mode.

A close examination of the $J$, $H$ and $K_s$ (Fig. 1) and $I$ images reveals that the stellar profiles of two stars in the field, namely [KG2001]102 B and Anon1, appear elongated. In order to probe the meaning of this asymmetric profile, we subtracted the point-spread function (PSF) of a single star from the observed profile of the two elongated sources. A

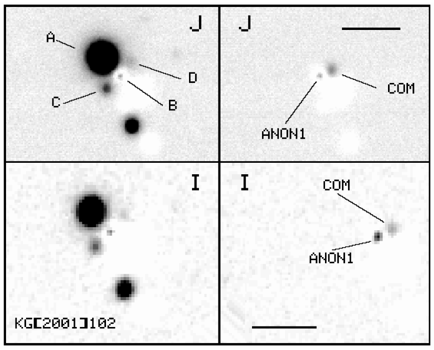


**Fig. 2.** Clay/PANIC $J$ (top panels) and Baade/IMACS $I$ (bottom panels) residual images of [KG2001]102 B and Anon1 that reveal the faint companions [KG2001]102 D and comAnon1. The horizontal bars are 5″ long; the scale is the same for each filter. North is up and east is to the left. The measured separations and position angles are 2.23″and 225° for AB, 1.64″ and 130° for BC, 1.42″ and 321° for BD and 1.10″ and 295° for Anon1 and its companion.

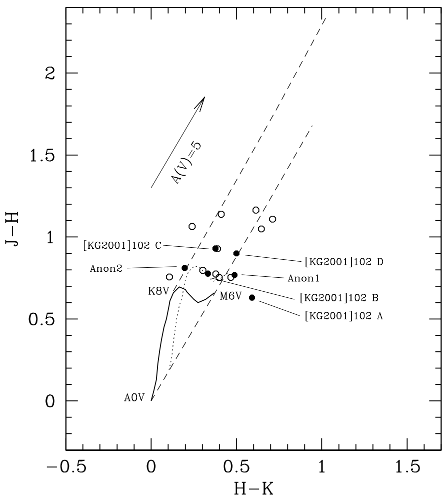


**Fig. 3.** $J-H$ vs. $H-K_s$ diagram of the sources detected. The solid line marks the locus of the main sequence, while the dashed lines define the standard reddening vector. The length of the arrow represents $A_V = 5$. The dotted line represent the main sequece reddened by $E(J-K) = 0.23$.

straight subtraction of a normalized and shifted image exposes any nearby extended emission or close companion. The left panels of Fig. 2 show the $J$, $I$ images for [KG2001]102 B while the right panels present the same for Anon1. In each of these two cases, a close faint companion is clearly seen to the NW, though the position angles differ for the two stars. In all $H_2$, $J$, $H$, $K_s$ frames and in the two $I$ independent frames, practically identical residuals were found. The positions of these companions, named [KG2001]102 D and comAnon1, were measured on all our subtracted frames and the mean values are listed in Table 1 together with their photometry also measured on the residual images. All the four components lie within a radius of ∼2″, while the separation of comAnon1 relative to Anon1 is 1.10″ .

From comparing the $K_s$ with the $H_2$ images (see Fig. 1), we were unable to detect any $H_2$ emission knots brighter than our sensitivity limit of $\sim 6 \times 10^{-32}$ W/m$^2$ Hz arcsec$^2$.

The spectrum of component B of [KG2001]102 was classified as K7V with a large uncertainty, and no classification was feasible for component C because of low signal to noise, but a late-M or later type is ruled out for this star.

Near-infrared color-color and magnitude-color diagrams are useful tools to understand the nature of the sources detected in photometric surveys. Fig. 3 shows the the $J-H$ vs. $H-K_s$ of the seventeen sources that we detected in an area of size 55″×55″ around [KG2001]102.The filled circles correspond to the four stellar components of [KG2001]102, all listed in Table 1. Component A shows significant near-IR excess emission, probably originating in a circumstellar dust envelope or disk. The stars with $J-H$ colors larger than unity, implying $E(J-H) > 0.38$ or $A_V > 3.7$, are most probably background stars.

In the case of component C, if it were an M0V star, the latest possible given that only very weak TiO bands can be traced in its noisy spectrum (see Fig. 3), its distance and extinction would be between 1.6 to 2.3 kpc and $A_V$ = 2.5. No realistic solution exists for an evolved star (luminossity class III, II or I) for this or any of the other stars reported here as, in all cases, their distance from the Sun would be well in excess of 20 kpc, outside the Milky Way.

A group of stars with $J - H$ around 0.75, which includes [KG2001]102 B, appear to form a set of main sequence M2-M5 stars reddened by the same $E(J - H) \simeq 0.17$, corresponding to $A_V = 1.5$, as shown in Fig. 3. However, we estimated a K7V spectral type for [KG2001]102 B. Assuming for this spectral type an intrinsic color index $(J - H)_\circ = 0.66$ and absolute magnitudes $M_J = 5.7$, $M_K = 4.9$, its distance from the Sun would be around 550 pc, which would place it behind the Cha I cloud, compatible with the absence of signposts of chromospheric activity in its spectrum. Its color excess would be $E(J - H) \simeq 0.13$, which corresponds to $A_V \simeq 1.2$. This is surprising because background stars are expected to be more highly reddened than any star member of the cloud. According to the exctinction map of the Cha I cloud by Cambrèsy et al. (1997), the mean total extinction caused by the cloud at the position of our field is in the range $3.0 < A_V < 3.5$. As both, our analysis and Cambrèsy et al.'s study, are based on $J$ magnitudes, the argument is independent of the reddening law assumed. We tested the possibility of a local dust column density inhomogeneity in the cloud at the position of [KG2001]102, that is, a "hole" of diameter of a less than one thousand AU (a few arcseconds) that would permit the detection of a number of background stars with extinctions lower that the local average. We performed star-count analyses on $J$, $H$ and $K$ *2MASS* images centered on [KG2001]102 and found no evidence of the existence of such local lower-extinction region.

Probably the answer to this dilemma lies in the incorrect assumption that the intrinsic $JHK$ colors of these stars correspond to those indicated by their spectral type. Indeed, the location of these stars on the $J - H$ vs. $H - K$ diagram is incompatible with their spectra unless they have strong $K$-band excess emission, a possibility that contradicts the fact that these stars display H$\alpha$ line in absorption, not in emission.

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