WDS 15249+5858 = BUP 162: The First Binary With a Substellar Object Around a Giant Star?

Francisco M. Rica Romero

Coordinator of LIADA Double Star Group
Astronomical Society of Mérida, Spain

frica0@terra.es

Abstract: This work reports on a study of the stellar system BUP 162 [mg. 3.42 and 8,87; sp. K2III and M0III, 50° and 254"8] which primary component, Iota Draconis, is the first and only red giant star with a substellar object around it. The original discoverers commented about the possible physical relationship between Iota Draconis and this wide visual companion. The LIADA Double Star Section informed the discoverers of our study of BUP 162 and they are very interested in the results. We concluded that BUP 162 is an optical pair. We also searched for unknown companions bound to Iota Draconis, but found none.

Introduction

The studies of visual double stars and their components carried out by LIADA's (*Liga Iberoamericana de Astronomia*) Double Star Section since 2001 confirm the excellent opportunities for amateurs who wish to participate in semi-professional astrophysical investigations. Amateurs have the opportunity to collaborate with professionals, but before this can happen, we must demonstrate our capability to them. In the visual double star field there are no projects where amateurs and professionals collaborate with each other (except the relation between Brian Mason and amateurs in general).

Figure 1 is a DSS image of ι Draconis. Sabine Frink, *et al.* discovered in 2002 a substellar companion to Iota Draconis, a 3.42 magnitude K2III red giant at a distance of 31 pc, making it the first known giant to have a substellar companion. Iota Draconis is the primary component of the system, WDS 15249+5858 = BUP 162, whose secondary component is an 8.87 magnitude star at 254.8" in direction 50°. Frink, *et al.* (Figure 2) commented in their investigation about the nature of BUP 162. LIADA's Double Star Section informed Sabine about the investigation that we are going to carry out on BUP 162, and they are very interested in the results.

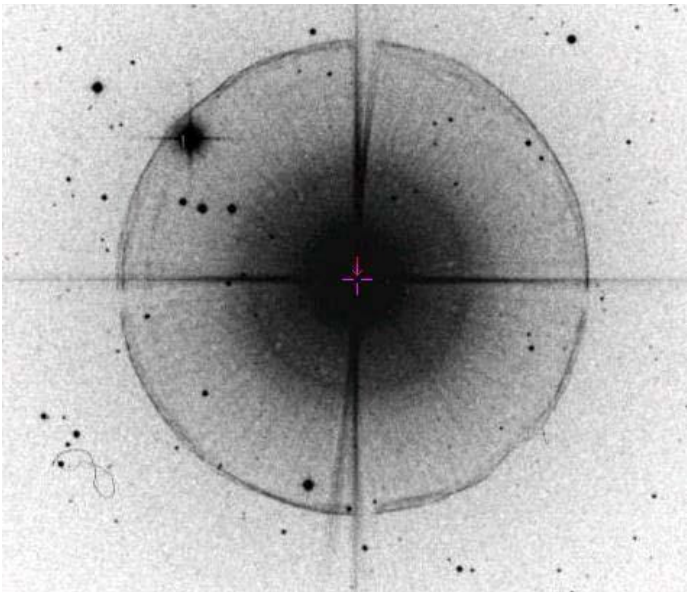

Figure 1: ι Draconis and its wide companion from the Digitized Sky Survey.

Professional Astronomical Literature

Tycho-2 B, V and I optical photometry, 2MASS J, H and K infrared photometry and Hipparcos/Tycho-2 proper motions were obtained from the Stellar Data Center of Strasburg (France).

In astronomical literature there are many works studying Iota Draconis which classify it as a K0-2 III red giant. The Hipparcos satellite obtained a trigonometric parallax corresponding with a distance of 31 pc. In spite of the fact that Iota Draconis is star located very near to us, its proper motion is very small. According to its apparent magnitude and trigonomet-

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ric parallax obtained by Hipparcos satellite, the absolute magnitude is +0.8.

A recent investigation (Santos, 2003) determined a metallicity [Fe/H] = +0,09 and interstellar absorption, Av, of +0.03 magnitude. Santos also calculated the heliocentric components of the galactic velocity: (U,V,W) = (-2.2, -7.0, -8,2). The stellar mass for Iota Draconis is 1.05 $M_{\odot}$¤.

The secondary is listed as a K7 star in several professional references; in the only reference where the luminosity class was obtained (Bartaya, 1983) the secondary was considered as a gMA star (a M giant star).

Both components of BUP 162 are listed in the New Suspected Variable Star Catalog (NSV) as NSV 7077 and NSV 7081. Several decades later an investigation re-vealed no variability in Iota Draconis.

Astrophysical data for WDS 15249+5858 are summarized in Table 1.

Spectral type and spectroscopy distance

Spectral types and luminosity classes for the components were estimated in the same way as in my work "GSC1753-1506: Discovery of a new binary" (JDSO vol. 1, Nº 1, 2005).

According to photometric and kinematic data BUP 162 is composed of two giants K1-2 III and M0III in good agreement with astronomical literature. The JHK two color diagram and the reduced proper motions diagram show the giant nature of the secondary. We calculate a spectroscopic distance of 39 pc for the primary in agreement with Hipparcos results (31 pc).

The spectral type of the secondary is in excellent agreement with Bartaya (1983). Our absolute magnitude was –0.4 and the spectroscopic distance obtained is about 625 pc.

I studied the reddening using the work of Burtein and Heiles (1982) and the Schlegel et al. (1998). I took into account the galactic latitudes (+48º) and the stellar distances. Interstellar absorptions , Av, of < 0.01 and 0.03 for both components were obtained.

Is BUP 162 a visual binary star?

To study the nature of BUP 162 BVIJHK photometry, individual proper motions and historical relative astrometry from Washington Double Star

passing through the large central circle and any given circle representing an abscissa measurement.

5. THE HOST STAR ι Dra

5.1. *ι Dra: A Visual Binary?*

The host star ι Dra is listed in the Washington Double Star (WDS; Worley & Douglass 1997) catalog as a visual binary with a separation of 254.″6 and a position angle of 50°. The observation dates back to 1879. The fainter component is BD +59°1655 (ι Dra itself is BD +59°1654) with a *V* magnitude of 8.76 mag in Tycho-1 (suspected to be intrinsically variable); at a distance of 31 pc this would be compatible with a late K dwarf, and most catalogs list the spectral type as K7. Bartaya (1983), on the other hand, classified the potential secondary as an M giant, which would clearly place it at a much larger distance.

The system was considered a visual double on the basis of similar proper motions by Burnham. Consequently, it is also included in the Catalogue of the Components of Double and Multiple Stars (Dommanget & Nys 1994) as CCDM 15250+5859.

However, modern proper motions (see Table 3) show that there is a difference of about 15 mas yr^{-1} in the total proper motion (or 2 km s^{-1} at a distance of 31 pc), which challenges the physical visual binary hypothesis. At a separation of 4.″2 (confirmed by the modern positions), which corresponds to a physical separation of 7900 AU, the expected period is of the order of 500,000 days. For a circular orbit, this would correspond to a relative velocity of about 500 m s^{-1} or 3 mas yr^{-1}, too small to explain the large observed proper-motion differences. Significant eccentricity may be able to produce the observed difference in motions. However, we conclude that the evidence for a physical relation between the two stars is weak.

5.2. *Stellar Parameters of ι Dra*

The mass of ι Dra has been determined to be 1.05 ± 0.36 $M_{\odot}$ by Allende Prieto & Lambert (1999) via a comparison of theoretical isochrones by Bertelli et al. (1994) with the absolute visual magnitude and *B*–*V* color based on *Hipparcos* data. Using the more recent evolutionary tracks by Yi et al. (2001) and their conversion to the observational (*B*–*V*,

Figure 2: Fragment from the paper of Sabine Flink et al. (2002) where the new substellar companion to the red giant star was reported.

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Catalogue (WDS) catalog were studied.

A very important datum is the relative motion of the system. From this datum I obtained two results: first using individual proper motions and second using historical relative measures. Using the individual proper motions, the relative motion of the system was calculated as the difference, in AR and DEC, of the individual motions. The Tycho-2 proper motions have a standard error of only 0.001"/year. I obtained a relative motion of $\mu(\alpha)$ = +9 ± 1 m.a.s./year and $\mu(\delta)$ = -23 ± 1 m.a.s./year.

To confirm the result I calculated the relative motion of the system by the historical relative astrometries plotting *X* (= rho * sin(theta)) and *Y* (= rho * cos(theta)) against epoch (theta was corrected by precession and proper motion). I obtained a relative motion of $\mu(\alpha)$ = +7 m.a.s./year and $\mu(\delta)$ = -24 m.a.s./year.

I was interested in studying individual proper motions to calculate the probability that BUP 162 is a common proper motion pair. The gaussian distribution was studied for $\mu(\alpha)$ and $\mu(\delta)$. Since the individual motion of the components of a binary star is slightly different due to the keplerian motion, I allowed a difference of 5% in the individual motions. According to our study there is no probability that BUP 162 is a common proper motion pair and so it is an optical pair.

BUP 162 is composed of a K2III star and a M0III star located at 31 pc and 625 pc, so the difference in distance modulus is +6.8 and we can be sure that both stars are located at very different distances.

According to the relative motion of the system and the difference in distance modulus in addition to the criteria of other investigators I can conclude that BUP 162 is clearly an optical pair.

Search for new bound companions

	Primary Component Iota Dra = HD 137759 = NSV7077	Secondary Component HD 238461 = NSV 7081
V	+3.29 (a)	+8.70 (b)
B − V	+1.17 (a)	+1.65 (b)
V − I	+1.07 (a)	---
K	0.68 (f)	+5.77 (c)
J − H (c)	---	+0.77
H − K (c)	---	+0.23
J − K	1.23 (f)	+1.00 (c)
Flux 12 µm [Jy] (i)	2.35	0.502
Flux 25 µm [Jy] (i)	5.78	0.250
Flux 60 µm [Jy] (i)	0.959	0.400
Flux 100 µm [Jy] (i)	0.563	1.00
µ(α) [mas/year]	-8.3 ± 0,4 (a)	+1 ± 1 (b)
µ(δ) [mas/year]	+17.3 ± 0.5 (a)	-6 ± 1 (b)
Spectral Types	K0III - K2III (d)	K7 (d); gM (e)
Distance [pc]	31 pc (a)	---
[Fe/H]	+0.09 (g)	---
Av	+0.03 (g)	---
(U,V,W) [km/s]	(-2.2, -7.0, -8.2) (g)	---
Mass [Solar Mass = 1]	1.05 (h)	---

a) Hipparcos Catalog; (b) Tycho-2 Catalog; (c) Two Micron All Sky Survey; (d) several sources; (e) Bartaya (1983); (f) Morel (1978); (g) Santos (2003); (i) MSX Infrared Astrometric Catalog (Egan, 1996)

Table 1: Astrophysical data for components of WDS 15249+5858 = BUP 162 in the astronomical literature

Iota Draconis is a nearby star with a small proper motion. So I didn't search for common proper motion companions. Instead I searched for companions by plotting them in a color-magnitude diagram where apparent 2MASS J-K and K data were plotted. A dwarf sequence to the Iota Draconis' distance was also plotted. So dwarf companion candidates must be located on or near this dwarf sequence. Subdwarf or white dwarf companions will not be detected unless we use reduced proper motion diagrams. Giant companions will be bright enough to be detected and they will be located well above the dwarf sequence.

What sky region to search? H.A. Abt's work (1988) was used to define the sky region to search. Abt obtained a relation between the stellar masses of the primary and the maximum separation in A.U. For a 1.05 solar mass star the maximum separation is 2,695

A.U. which corresponds to 85" at Iota Draconis' distance. I multiplied this value by three and searched a 300" sky region.

I selected our sample using 2MASS where only stars located within 300" of Iota Draconis and with a S/N > 10 where selected. No star was found at a distance similar to 32 pc.

Against the sample the most interesting object was a weak star of +18.0 magnitude which VJHK colors and kinematical data corresponding to a M4/4.5V red dwarf located at a distance of about 70-90 pc which likely belongs to a young disk population. The USNO-B1.0 catalog lists a proper motion of $\mu(\alpha)$ = -44 ± 3 mas/year and $\mu(\delta)$ = +60 mas/year.

Conclusions

A study of the wide system BUP 162 was carried out using BVJHK photometry and proper motions from Hipparcos, Tycho-2 and 2MASS catalogs. Spectral types and luminosity classes were estimated photometrically and kinematically using two-color diagrams and reduced proper motions diagrams (K2III + M0III). The results showed very good agreement with professional astronomical literature. The relative motion was obtained independently using individual proper motions and historical relative measures. Several professional criteria were used to obtain the true nature of this pair. The difference in proper motions and in photometric distance are the main results that lead to the conclusion that BUP 162 is clearly optical in nature.

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