Study of the double star DBR 89

EPIC ID 211089792

TYC ID 1818-1428-1

AD gaia 62.6704194° +/-0.3 mas DE gaia +24.4016589°+/-0.2 mas

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April 2017

Abstract :

This paper presents a work aiming at the determination of the nature, either physical or optical, of a double star called DBR 89, one of the components of which has a planet (exoplanet). The photometric distances of the two components are estimated and found to be very close. This result suports the hypothesis that this pair constitutes a physical binary. This hypothesis is confirmed by a statistical test and by the fact that the two stars have common proper motions, in agreement with the detailed study carried out by other authors.

Key words : double stars, distances.

Reading the article[1] by Marie-Claude Paskoff, published in the journal « Observations et Travaux n ° 52 Spécial Étoiles Doubles (pages 59 to 62) » entitled "Les Lycéens dans les étoiles ... doubles", led me to take an interest in determination of the distance of observed stars. The objective of the method is to try to answer the following question: Is the observed couple of stars a physical pair or an optical pair? If the distances of the components to the observer are very different, the coupleof stars is optical; otherwise it is probable that it is a physical pair whose components are linked by gravitation. I presented a first draft of this work at the meeting of the Double Stars Committee of the « Société Astronomique de France » which was held in Lille in September 2016. On the basis of the remarks made by the scientific advisers of the committee present at this meeting, I refined the method. Of course, this criterion of distance is not sufficient on its own to decide; it is necessary to supplement it with other elements when they are known - trigonometric parallax, proper motions, radial velocities - without forgetting the statistical aspect by determining the probability that an object is at the given angular separation of the observed star.

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[1] http://articles.adsabs.harvard.edu/full/seri/O+T../0052/0000059.000.html

I) Choice of target

I chose the star EPIC-211089792, listed DBR 89 in the WDS[2] (The Washington Visual Double Star Catalog (Mason + 2001-2014)) and particularly well studied since the detection of a new exoplanet by the Super-WASP observatory then by the K2[3] space mission during its fourth campaign: a hot Jupiter EPIC-211089792b. A call for observations was launched by Alexandre Santerne in early January 2016. I participated in this work by providing images in the B, V and R bands of the target, obtained on 8 January 2016 with the Faulkes Telescope North[4] (FTN) located at the top of the Haleakala in Hawaii (3 B-frames, 3 V-frames and 3 R-frames, 20s each). In fact, there is a "contaminant" at 4.3 "NE of the target, BVR images are used to estimate contamination by the presence of the second component which could not be resolved by the data recorded by the mission Kepler K2 The results are published in the article by Alexandre Santerne: "EPIC211089792 B: AN ALIGNED AND INFLATED HOT JUPITER IN A YOUNG VISUAL BINARY" published in "The Astrophysical Journal, Volume 824, Number 1"[5].

I also made images in B and V on January 19, 2017 with the FTN and the FTS (Faulkes Telescope South[6]) as well as February 2 and 3, 2017 with the FTN.

II) Distance module method

1) Position measurements of components A and B of the DBR 89 pair on the images obtained on January 8, 2016 from FTN (Astrometrica[7] and GAIA-DR1 catalog).

See Figure 1 and Table 1.

2) Measurement of the angle of position θ (°) and the angular separation ρ ('') of the components of the DBR 89 pair (REDUC[8], calibration of the images with two pairs of reference stars giving the CCD orientation Δ(°) and the sampling E ('' / pix)of images).

In our study the two pairs of stars chosen for the calibration are:

C1 = UCAC4 573-010526 ; RA = 04h10m32.57s DEC = + 24 ° 28'28.0 ''

C2 = UCAC4 573-010525 ; RA = 04h10m31.09s DEC = + 24 ° 28'16.8 ''

and

C'1 = UCAC4 573-010519 ; RA = 04h10m25.88s DEC = 24 ° 24'36.4 ''

C'2 = UCAC4 573-010520 ; RA = 04h10m26.37s DEC = 24 ° 24'38.8 ''

The coordinates of these stars are measured on an image of January 8, 2016 using the software Astrometrica and the catalog GAIA-DR1 to calculate the polar coordinates of the two reference pairs.

See Figure 1 and Table 1.

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[2] http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/WDS
[3] http://keplerscience.arc.nasa.gov/objectives.html
[4] https://lco.global/observatory/2m/faulkes-telescope-north/
[5] https://arxiv.org/pdf/1601.07680.pdf
[6] https://lco.global/observatory/2m/faulkes-telescope-south/
[7] http://www.astrometrica.at/
[8] http://www.astrosurf.com/hfosaf/uk/tdownload.htm#reduc

3) Photometric measurements of the components of the DBR 89 (SUBARU Image Processor[9]: Makali`i with two reference stars).

The two reference stars used are:

R1 = UCAC4 573-010534 ; Bmag = 13.564 +/- 0.059; Vmag = 12.729 +/- 0.034; Rmag = 12.408 ± 0.044

R2 = UCAC4 572-010342 ; Bmag = 13.131 +/- 0.044; Vmag = 12.389 +/- 0.043; Rmag = 12.134 +/- 0.048

The data come from the APASS catalog (AAVSO Photometric All Sky Survey DR9 (Henden +, 2016))

The magnitudes measurements of the components A and B of the DBR 89 pair are performed in 3-circle aperture photometry.

See Figure 1 and Table 2.

4) Interstellar extinction correction

a) $E\,(B\text{-}V) = (B\text{-}V)_{measured} - (B\text{-}V)_{corrected}$

The extinction depends on the wavelength λ, it is stronger in the blue, which means that the objects appear redder than they actually are.

$m_{corrected} = m_{real} - A$

Where "A" is the extinction measured in magnitude

$A_{\lambda} = R_{\lambda} \times E\,(B\text{-}V)$ according to "Les Cahiers Clairaut[10] Spring 2008 n ° 121 page 4)

the following values are commonly allowed:

- For blue $A_B = 4.315 \times E\,(B\text{-}V)$

- For green $A_V = 3.315 \times E\,(B\text{-}V)$

- For red $A_R = 2.673 \times E\,(B\text{-}V)$

b) Determination of the absolute magnitude of each component of the DBR 89 pair

We use the tables established by Frédéric Arenou linking color index, spectral type, class of luminosity and absolute magnitude. The study by Alexandre Santerne[5] on page 4 gives information on the spectral type and the class of luminosity of the two components of the DBR 89 pair.

See table 2- the values used are extracted from the table of Frédéric Arenou.

In our case E (B-V) = 0.19 (see the article by Alexandre Santerne[5] page 7: Reddening E (B-V) [mag] 0.19 ± 0.02)

- $A_B = 0.81985$

- $A_V = 0.62985$

- $A_R = 0.50787$

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[9] https://makalii.mtk.nao.ac.jp/

[10] http://acces.ens-lyon.fr/clea/archives/cahiers-clairaut/CLEA_CahiersClairaut_121_02.pdf

The magnitudes measurements of the two components in the 3 previous bands B, V and R are thus corrected for extinction.

See Table 3.

5) <u>Corrected Color Index</u>

After calculating the weighted averages of the magnitudes of the two components in B and V, we then calculate the corrected color index for each component of the studied pair, taking into account extinction in blue and green.

See Table 3.

6) <u>Distance calculations of the components A and B of the studied couple</u>

Pogson's law makes it possible to calculate the distance of an object knowing its apparent magnitude and its absolute magnitude:

$\log d = (m_V - A_V - M_V + 5) / 5$

$d = 10^{((mv-Av-Mv+5)/5)}$

See table 4.

7) <u>Error calculations</u>

a) On the magnitudes of each component measured in V-band on the images obtained from the Faulkes Telescopes.

Vmag A = 12.520 +/- 0.013

Vmag B = 14.690 +/- 0.031

b) On the absorption in V-band

A_V = 0.630 +/- 0.066 (3.315 x 0.02 mag)

c) On the absolute magnitude M

The uncertainty on the absolute magnitude is estimated by Frédéric Arenou when establishing his tables at 0.3 mag for each component. We thus see that this latter uncertainty is significantly greater than the errors on the apparent magnitudes and on the absorption.

Finally,

$\sigma d / d = \sigma M \times \ln(10) / 5$

This is an uncertainty of about 14% over the distance of each component. The difference of the distances of each component is less than the error on these distances, which makes it possible to suppose that the two stars can be at the same distance and thus constitute a physical pair.

See Table 4

III) **Components proper motions**

1) My research with the latest catalog UCAC5 (Zacharias + 2017) gives me the proper movements in right ascension and declination of the two components:

Component A: Src ID gaia 150054784248952576

pmAD (UCAC / Gaia proper motion in RA * cosDE) 15.2 mas / year +/- 1.2 mas / year

pmDE (UCAC / Gaia proper motion in DE) -22.8 mas / year +/- 1.2 mas / year

Component B: Src IDgaia 150054784249943040

pmAD (UCAC / Gaia proper motion in RA * cosDE) 16.4 mas / year +/- 2.0 mas / year

pmDE (UCAC / Gaia proper motion in DE) -25.5 mas / year +/- 2.0 mas / year

The two components have common proper motions which confirm the physical binary nature of DBR 89.

2) Archive Images

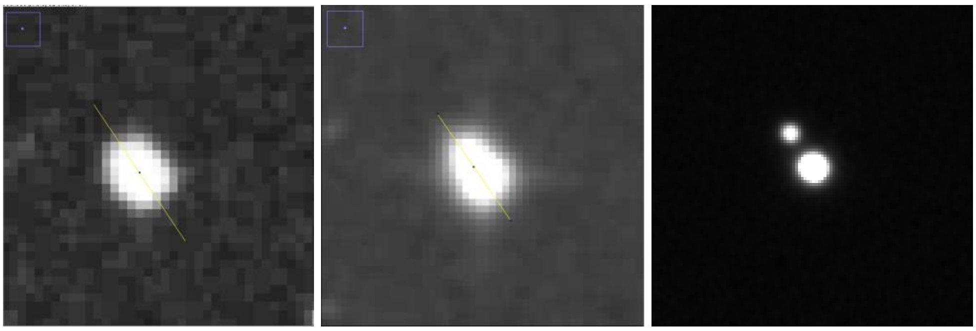
- The CDS portal[11]l gives us:

POSSI survey on 1949/12/21, sampling 1.6''/pix

POSSII survey on 1993/12/11, sampling 1.0''/pix

- On the other hand, my observations at the Faulkes Telescope North of the Las Cumbres Observatory network provide, for example, this image:

FTN V-band on 2016/01/08, sampling 0.3 ''/pix



1949	1993	2016
θ ~ 35°	θ ~ 37°	θ = 34.15°
ρ ~ 3''	ρ ~ 4.5''	ρ = 4.32''

The images of 1949, 1993 and ours of 2016 show the two components moving together in the time thus presenting common proper motions which reinforces the physical reality of the couple.

[11] http://cdsweb.u-strasbg.fr

IV) **Statistical Testing**

I used the relationship given in the "wiki"[12] written by Frédéric Arenou.

We can evaluate the probability of having an object at the angular separation ρ (in arc seconds) of a given star, its presence being due to chance alone.

The probability of having at least one star of magnitude m in the surface element $\pi \rho^2$ around a given star is obtained with the Poisson law by:

$$P(\rho, m) = 1\text{-}\exp(-\pi \rho^2 D)$$

The field of the images obtained with the Faulkes Telescope 2 meters in diameter is approximately 10'x10 'or an area of 600''x600''.

The use of ALADIN and the VizieR catalog service (choice of the NOMAD catalog) makes it possible to count the number of stars of the field whose magnitude in band V is less than or equal to a given magnitude.

I counted 7 stars in magnitude brighter than 14.06 in a 10 'x 10' field.

Let D = 7 / (600) x (600) = D / 360000

$P(4.3; 14.06) = 1\text{-}\exp(-\pi \times 4.3^2 \times 7/360000) = 0.0011$

Let 1 chance out of 886 have at least one star by chance at 4.3'' of the component A or 0.1%.

This reinforces the option "physical couple

Note: As an historical example, the notion of using separation to estimate the probability of "physicity" has been used for a long time. For example, Robert Aitken[13] discusses it and gives a formula in the introduction to his ADS catalog of 1932 (ancestor of the WDS).

V) Conclusion

The difference between the distances of the components obtained here and the results of Alexandre Santerne can be explained by taking into account, in order to calculate the distance, all available magnitudes (from blue to thermal infrared). With this data, an energy spectral distribution (SED) model has been adjusted. The main parameters of this model are the distance and the extinction (assuming that the stellar properties, in particular the effective temperature Teff) are known. The model provides a distance with a precision of 3pc by exploiting the information provided by several bands and not by a single band as is the case in this article.

See Table 5

The different methods used show that it is certainly a physical couple, which confirms Alexander Santerne's article. DBR 89 would therefore be a long-time orbital binary (several centuries) located between the Pleiades and the Hyades.

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[12] https://en.wikipedia.org/wiki/Double_star

[13] Science, Volume 76, Issue 1961, pp. 103-104, " New General Catalogue of Double Stars within 120 degrees of the North Pole"

Fig. 1 - In ALADIN, field of DBR 89, calibration stars for astrometry and reference stars for photometry.

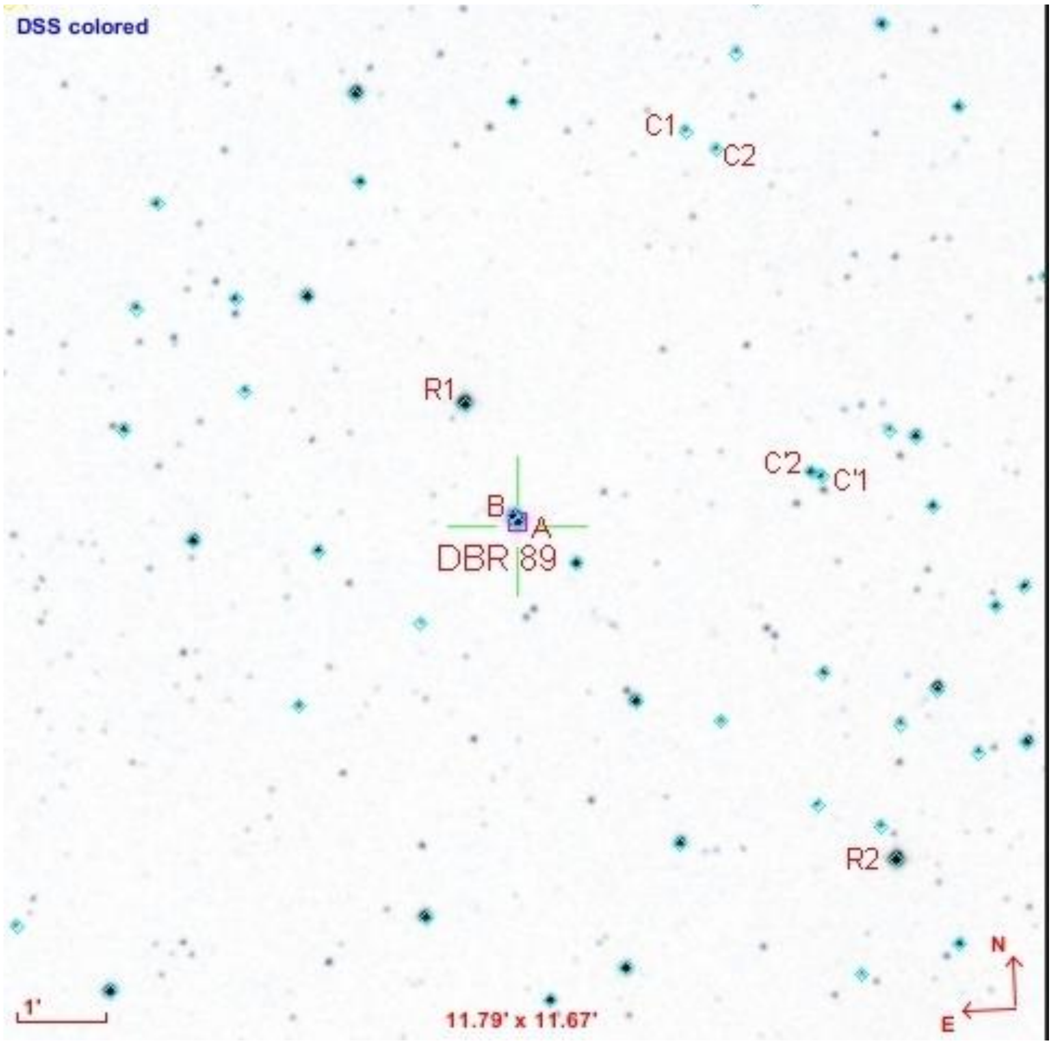

Table 1 - Data and observation journal of the stellar couple DBR 89

	DBR 89 = EPIC 211089792 = UCAC4 573-010529	
Position (J2000)	RA = 04h10m40.91s	DEC = +24°24'05.9''
WDS id	04107+2424	
Couples for calibration	C_1C_2	$C'_1C'_2$
θ(°)	241.00049	70.27287
ρ('')	23.101991	7.1102648
Dates	08/01/2016 2016.024	19/01/2017 2017.053
Δ(°)	-0.065	0.400
S(''/pix)	0.304200	0.300365
Position angle θ(°)	34.1	34.2
Angular separation ρ('')	4.33	4.31
Mean airmass	1.03	1.09

Table 2 - Spectral types, classesof luminosity, color index and absolute magnitudes.

Component A				Component B			
Type	Classe	(B-V)	M	Type	Classe	(B-V)	M
G7	V	0.72	5.4	K5	V	1.15	7.4

Table 3 - Apparent magnitudes of the two components of the DBR 89 pair and corrections due to extinction at different wavelengths.

date	site	Number of observations			Component A			Component B		
		B	V	R	B_{magA}	V_{magA}	R_{magA}	B_{magB}	V_{magB}	R_{magB}
20160108	FTN	3	3	3	13.489	12.519	12.100	16.019	14.704	13.920
20170119	FTN	5	5		13.485	12.517		15.946	14.693	
20170131	FTN	10	10		13.479	12.513		15.990	14.706	
20170131	FTS	5	5		13.463	12.499		15.994	14.679	
20170202	FTN	15	14		13.482	12.521		15.987	14.702	
20170203	FTN	10	10		13.511	12.538		15.954	14.654	
Weighted averages		48	47	3	13.486 +/- 0.019	12.520 +/- 0.013	12.100 +/- 0.002	15.979 +/- 0.053	14.690 +/- 0.031	13.920 +/- 0.005
Extinction correction		a_B=-0.820	a_V=-0.630	a_R=-0.508	**B_{magA}** corrected	**V_{magA}** corrected	**R_{magA}** corrected	**B_{magB}** corrected	**V_{magB}** corrected	**R_{magB}** corrected
Corrected magnitudes					**12.666**	**11.890**	**11.592**	**15.159**	**14.060**	**13.412**
Color Index $(B-V)_{corrigé}$					**0.776 +/-0.023**			**1.099 +/-0.061**		

Table 4 - Distance calculations

Component A	Component B
M=5.4+/-0.3	M=7.4+/-0.3
m=11.890+/-0.067	m=14.060+/-0.099
d=199 pc +/-28 pc	**d=215 pc +/-28 pc**

Table 5 - Comparative Table

DBR 89	Our résultats	Data in A. Santerne's article
Position angle θ	34.15°	-
Angular separation ρ	4.32''	4.3''
V magnitudes	11.890/14.060	12.526/14.666
Spectral classes and types	-	G7V/K5V
Mean distance	200 pc	185 pc
Distance of components	864 UA	800 UA

Acknowledgments

The author warmly thanks Alexandre Santerne of the Laboratory of Astrophysics of Marseille (France) for organizing this fruitful collaboration between professionals and amateurs as well as the LCOGT network team which allows me to access the Faulkes Telescope. He also thanked Frédéric Arenou of the Observatory of Paris (France), William Harthopf of the US Naval Observatory (USA) for their advice and encouragement. Finally, he expresses his gratitude to Edgar Soulié and Daniel Bonneau, respectively president and scientific adviser of the of the Doubles Stars Committee of the « Société Astronomique de France », for the rereading of this article.

``This research has made use of

- the Washington Double Star Catalog maintained at the U.S. Naval Observatory.
- the VizieR catalogue access tool, CDS, Strasbourg, France. The original description of the VizieR service was published in A&AS 143, 23"