BU 787 AB: An Orbital Binary with Optical Nature

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Abstract: BU 787 AB is a double star composed of a bright and blue B9V star of 7.35 magnitude and a white (A0V) secondary of 11.9 magnitude, separated by 5.3". Erceg (1984) calculated orbital parameters for the first time for this double star. In this work, I report several CCD measures performed by some amateurs using telescopes with apertures that range from 0.2 to 0.4 meters. I suspected the possible optical nature of BU 787 AB and decided to perform a detailed astrophysical study of the stellar components and the dynamics of the double star. Several astrophysical tests were applied to determine the nature of BU 787 AB. All of them demonstrated, unambiguously, the optical nature of BU 787 AB.

Introduction

Nowadays, the works of the amateur are becoming more and more interesting because the difference between the technical levels of what professionals do and what amateurs do is closing. Rica (2008) reviewed some of the important work areas of amateur observers in the double star field. In an orbital calculation work, the author of this article found a binary star listed in the *Sixth Catalog of Orbits of Visual Binary Stars* (Hartkopf, Mason & Worley 2001) in which the basic astrophysical data looked suspect to him because of the possible optical nature for this "binary". The primary is a bright and white star (B9V/A0V) and so its luminosity (absolute magnitude) is bright. The distance modulus would be important and so the primary component would be far away from us. A distant binary with an angular separation of 5.3" in 2007/8 means that the projected separation would likely be a few hundred Astronomical Units (AU) and a large orbital period of thousands of years. But the relative (and linear) motion of B is very large and it is not what I expected for a very large orbital period (lower orbital motion is expected).

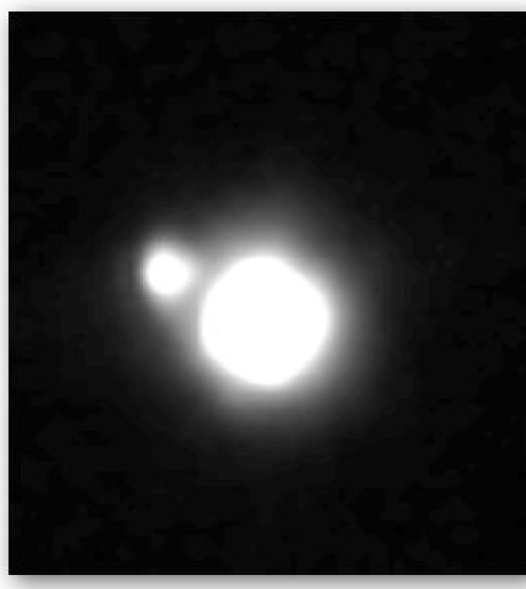

Figure 1: BU 787 AB in an image taken March 13, 2008 by Francisco Rica using a LX200R telescope with 0.4 m objective and a focal length of 4117 mm attached to a DMK 41AU02.AS camera. The instrument is located at the Astronomical Observatory of Cantabria (Spain).

In this work I comment, in detail, on the astrophysical study for BU 787 AB (=WDS 03342+4837) to determine the nature of this pair. See Figure 1.

The Astrophysical Study

A detailed astrophysical study for the stellar components and for the stellar system was performed. The lines of the astrophysical study were published in Benavides *et al.* (2010) in sections 3 to 10. In the following sections, I complete the report for this study.

X-Ray activity

The X-ray emission is related to the age of the stars and is inversely proportional to stellar age. While young stars are strong X-ray emitters, old stars are weak X-ray emitters. There are several diagrams that show the relation of X-ray emission with stellar age.

X-radiation is absorbed by the Earth's atmosphere, so instruments that detect X-rays must be taken to a high altitude. **ROSAT** was an X-ray satellite telescope designed by Germany. It was launched in 1990 and operated until 1999. The ROSAT All-Sky Survey (RASS) was the first imaging X-ray survey of the entire sky. X-ray digital images show X-ray sources with a very large FWHM of about 2 arcminutes and a calculation of the centroid is difficult, so the AR and DEC for the X-ray source are known with an error of even tens of arc seconds. Optical counterparts for the X-ray sources are not easy to identify, so the astrophysical search for optical counterparts is at an angular distance that ranges from 16 to 40 arcseconds.

Photometric data

The catalog of the Two Micron All Sky Survey (Cutri *et al.* 2000; hereafter 2MASS) lists data for the A and B components. While the photometric quality for JHK is good for the primary component, the photometric quality for the secondary is bad and it was not used in this work.

Astrometric Measures

BU 787 AB is composed of stars with magnitude 7.4 and 11.9 (WDS catalog), separated by more than 5" in the direction of 291 degrees. Since Burnham (1882) discovered its binary nature in 1881, it has had 16 measures which cover an arc of about 60 degrees; and the angular separation increased from 2.0" to 4.5". The measures performed were micrometric, with the use of a refractor or reflector telescope, but the measures were analyzed using the 2MASS CCD image. Some collaborators of the LIADA Double Star Section performed several measures in 2007-2008. These new measures are listed in Table 1 in bold font.

Our French friend Florent Losse made a measure in 2008.112 using a 0.2 meter telescope with a Barlow 2x lens (total focal length of 4340 mm). The CCD camera used was a CCD Audine with a KAF400 sensor. Florent took 200 images with two different exposure times. Francisco Rica, in March 2008, used a 0.4 meter LX200R telescope located in the Cantabria Astronomical Observatory (north of Spain). For the measures, a CCD ST-8XE was used at the primary focus (focal length of 4115 mm). Ten images of 15 seconds of exposure time were astrometrically reduced using Astrometrica 4.0 to determine the scale and orientation. The scale was of 0.45" per pixel. Ten images of 1 second of exposure time were used to determine θ and ρ using REDUC. Rafael Benavides from Cordoba (South of the Spain) measured this pair on January 16, 2007, using a C11 telescope (0.28 meters) with a focal length of 5420 mm and a pixel scale of 0.41x 0.38 arcseconds.

Table 1 lists the historical measures and the LIADA measures. This table has the following columns: the epoch of the observations, in column (1); θ (in degrees) and ρ (in arcseconds) values in columns (2) and (3); the number of measures in column (4); the observer code as listed in the WDS catalog, in column (5); last two columns list the residuals O-C with the official orbit.

Figure 2 shows a plot of θ versus epoch while Figure 3 shows a plot of ρ versus epoch. The red curves were plotted using the orbital parameters calculated by Erceg (1984) (see Section 4).

The Orbital Parameters

Erceg (1984) calculated the orbital parameters shown in Table 2.

Using the orbital parameters and Hipparcos parallax, a total mass of 2,602$M_{\odot}$ was obtained! This unrealistic total mass could be caused by terribly wrong orbital parameters or by an erroneous trigonometric parallax. To confirm that the orbital parameters are wrong, I obtained the typical absolute magnitude for

Table 2: Orbital parameters for BU 787 AB

P =	400.220 yr
To =	1831.930
e =	0.540
a =	2.8610"
i =	31.40°
ω =	331.90°
Ω =	147.30°

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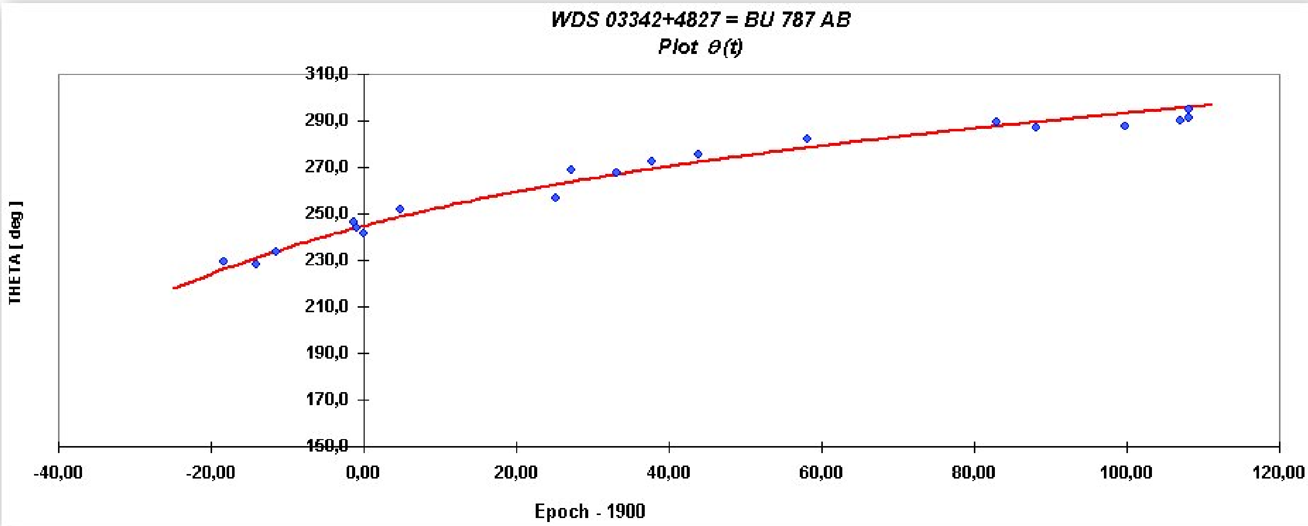

Figure 2: The plot shows the theta (θ) values vs the epoch of observations (filled blue points). The red curve was plotted using the orbital parameters calculated by Erceg (1984)

Table 1: Observations and Residuals of WDS 03342+4827, BU 787 AB

Epoch	θ [°]	ρ["]	N	Observer	Δθ[°]	Δρ ["]
1881.69	228.5	2.05	3	Bu	3.01	-0.052
1885.96	227.3	2.35	1	StH	-3.12	0.157
1888.588	233.1	2.02	5	Com	-0.16	-0.230
1898.704	245.6	2.39	1	Hu	2.60	-0.080
1899.13	243.3	2.4	1	Bu	-0.07	-0.079
1899.983	241	2.64	3	Doo	-3.10	0.142
1904.84	250.9	2.33	1	Bu	2.80	-0.273
1925.17	256.2	2.54	1	Fox	-5.68	-0.482
1927.14	268.2	2.52	2	Gcb	5.18	-0.540
1933.17	267.1	3.23	1	Gcb	0.76	0.056
1937.79	271.7	3.1	3	VBs	2.98	-0.159
1943.84	274.8	3.26	1	VBs	3.12	-0.105
1958.08	281.6	3.81	1	B	3.62	0.215
1983	289	4.3	1	Hei	1.54	0.377
1988.091	287.1	3.72	1	Pop	-2.12	-0.258
1999.86	287.6	4.51	1	TMA	-5.52	0.421
2007.0442	290.3	5.33	1	BVD	-5.08	1.185
2008.112	295.0	5.34	1	LOS	-0.69	1.187
2008.1995	291.3	5.30	1	FMR	-4.42	1.147

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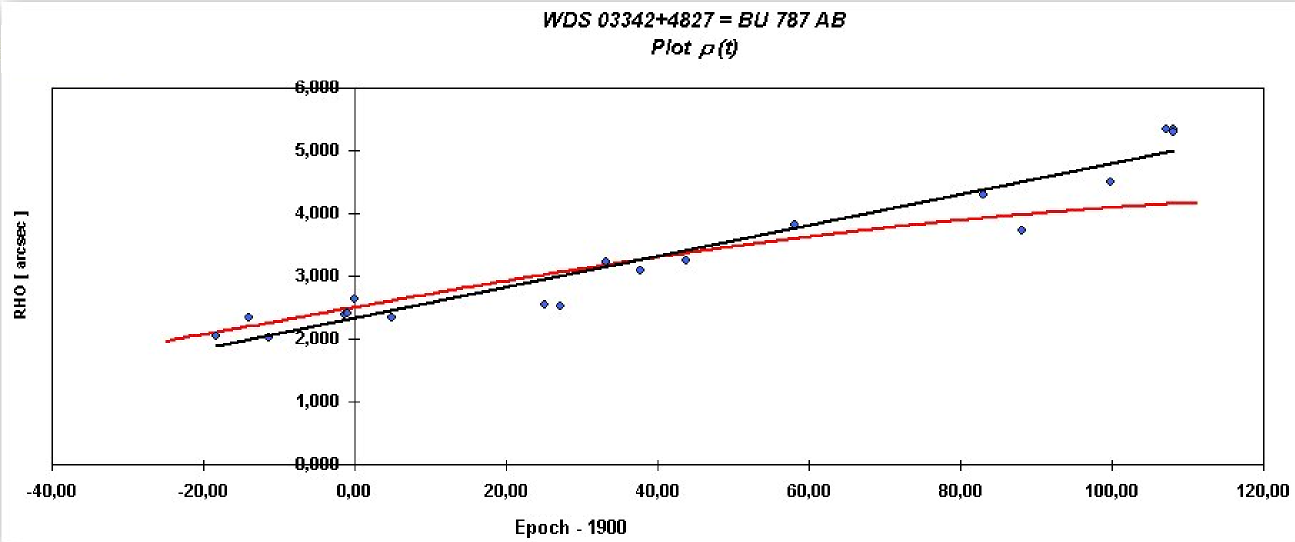

Figure 3: The plot shows the rho (ρ) values vs the epoch of observations (filled blue points). The red curve was plotted using the orbital parameters calculated by Erceg (1984). The black line is a linear fit.

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a B9V (the primary spectral type): about +0.30 to +0.35 magnitude. If I correct the V magnitude for the primary by interstellar reddening (Av = +0.35), then a distance of 223.3 pc is obtained. This corresponds to a parallax of about 0.0044" (in good agreement with the Hipparcos value of 0.0038"). Using this last value for the parallax, a total mass of 1,716 $M_\odot$ was obtained, so the orbital parameters are unrealistic.

Figure 4 shows the orbit calculated by Erceg (1984). The important residuals of the recent measures and the linear trajectory is evident.

Astrophysical data

The Tycho-2 catalog determined a proper motion of +22.5 ± 1.5 mas/yr in RA and -27.2 ± 1.6 mas/yr in DEC. The Hipparcos trigonometric parallax of 3.83 ± 0.72 mas corresponds to a distance of 261 $^{+60}/_{-40}$ pc.

In the astronomical literature, BU 787 AB has been classified as a B9V star (Jaschek, Conde, & de Sierra (1964), Morgan, Hiltner, & Garrison (1971)) and as a A0V (Kenedy (1983)) . In this work a combined spectral type of B9V (in excellent agreement with literature) was obtained using BVIJHK photometry and the combined proper motion. The stellar mass for the primary component is 3.8 solar masses. The spectral type of the secondary is unknown and I assumed a value of 1.0 solar mass.

In the literature there are many radial velocity values that range from -13 km/s to +0.7 km/s.

Age and Stellar Population

In this work a galactocentric velocity of (U,V,W) = (-21, -36, -11) km/s was calculated. According to Eggen's diagrams (1969a, 1969b) BU 787 AB is a member of the young galactic disk. Grenon (1987) defined a kinematic age parameter, fG. A value of 0.21 for fG was obtained in this work corresponding to middle age thin disk stars. Patience *et al*. (2002) list this double star belonging to the α Persei cluster of about 50 million years.

Tables 3 and 4 list the astrophysical parameters for the stellar components and the double star.

X-Ray Activity

ROSAT PSPC catalog lists an X-ray source near BU 787 AB. Randich *et al*. (1996) calculated an X-ray luminosity (log Lx) of 29.43 erg/s.

If I consult the diagram of Damiani *et al*. (1995), the X-ray activity of BU 787 AB is typical of a star with the age of several tens of millions of years. Giampapa, Prosser, and Fleming (1998) studied the X-ray emission of the 70 Myrs open cluster IC 4665. This cluster has an X-ray activity similar to BU 787 AB, so it can be said that BU 787 AB has a similar age with IC 4665, that is, about 70 Myrs.

BU 787 AB is a member of the α Persei cluster. This cluster has an age of about 50 Myrs, which is in good agreement with the age determined in this work by the X-ray luminosity.

Nature of BU 787 AB

Using historical measures, a weighted linear fit

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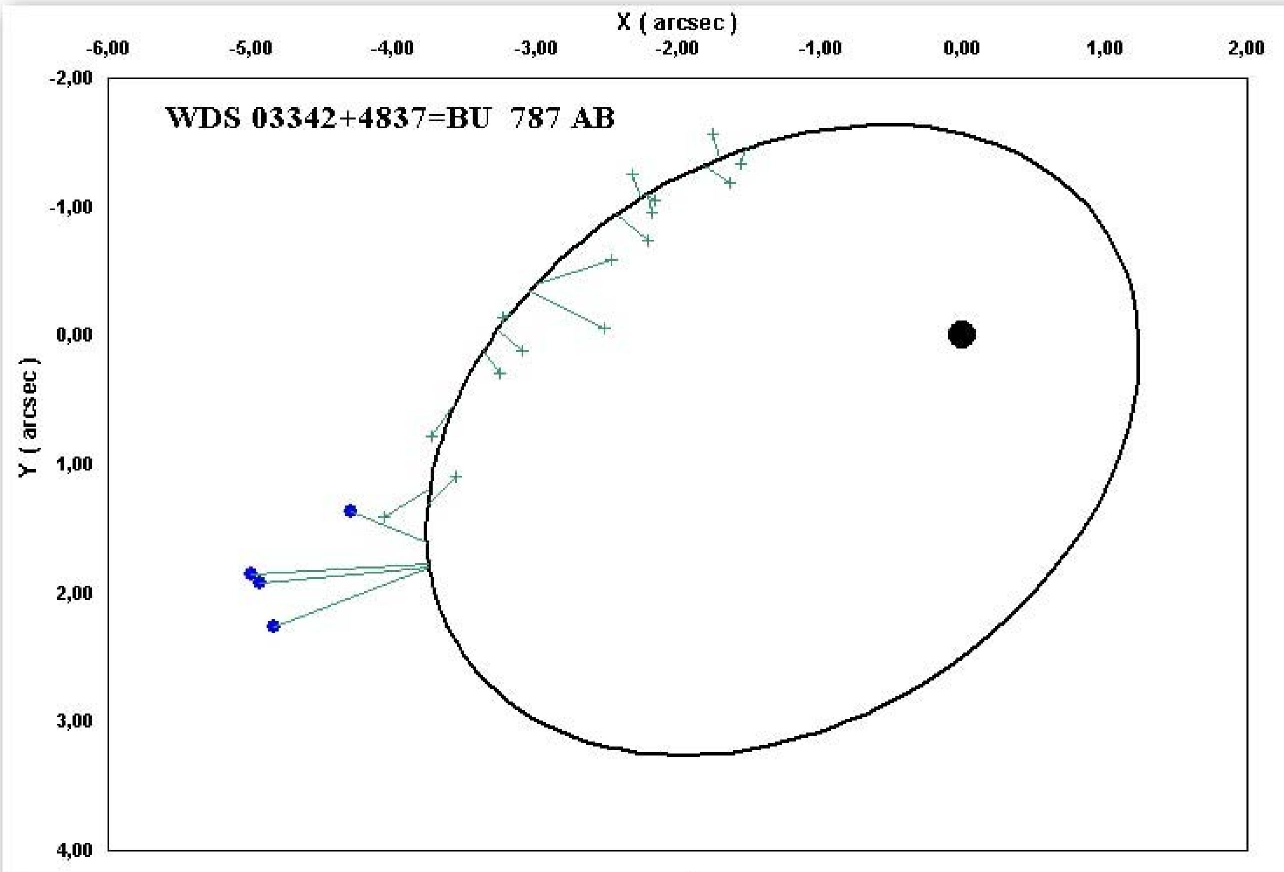

Figure 4: The orbit of BU 787 AB calculated by Erceg (1984). The visual micrometric measures are plotted as plus (+). Speckle points are represented as filled blue circles. The lines join the observations with the ephemerid calculated using orbital parameters. North is down and East is right.

was performed to calculate a relative motion of B with respect to A of $\Delta x = -24.2 \pm 1.4$ mas/yr and $\Delta y = +26.2 \pm 1.4$ mas/yr. The baseline of the 19 measures used was 126.51 years. From the proper motion of A and relative motion of B, I calculated $\mu(\alpha) = -1.7 \pm 2.1$ mas/yr and $\mu(\delta) = -1.0 \pm 2.2$ mas/yr for B.

According to the very different proper motions (much greater than 3σ) of B and A, it is likely that B is not gravitationally bound to A, and so it would be an optical companion. But, there exists the possibility that the orbital motion is much greater that the errors in the proper motions. In this case, the proper motion of the components would be incompatible from a mathematical point of view, but the pair of stars could be gravitationally bound by orbiting the center of mass, so I must confirm the nature of BU 787 AB using other tests.

I have used several tests (those of Dommanget (1955, 1956), Peter van de Kamp (1961) and Sinachopoulos & Mouzourakis (1992)) that are based on astromechanics. They are described in detail in Benavides *et al.* (2010). The Dommanget test determined that B would be bound to A if the stellar system is nearer than 30 pc. Hipparcos calculated a trigonometric parallax of 3.83 ± 0.72 mas, corresponding to a distance of $261^{+60}/_{-41}$ pc. Since the distance for A is 8.7 times greater that the limit of this criterion, it is clear that it is an optical pair.

For the criterion of van de Kamp, I need the stellar mass, the projected separation (957 AU), and the annual variation of theta (0.499 deg/yr). This criterion shows that the true critical value for a parabolic orbit is 379 AU^3 yr^{-2}, while the observed projected critical value is of 66,285 AU^3 yr^{-2}, which is much greater than the true value, so B is not bound to A.

The tangential velocity corresponding to the observed relative proper motion of B, with respect to A, is 44.6 km s^{-1}. Using the criterion of Sinachopoulos &

Table 3. Astrophysical data for BU 787 AB = WDS 03342+4837

	Primary	Secondary
α_{2000} c)	03h 34m 12.95s	
δ_{2000} c)	+48° 37' 3.1"	
V	7.35 c)	11.9 a)
B – V c)	+0.038 ± 0.005	…
V – I c)	+0.05 ± 0.00	…
K b)	7.21 ± 0.02	…
J – H b)	-0.09 ± 0.06	…
H – K b)	+0.04 ± 0.06	…
J – K b)	-0.05 ± 0.03	…
μ(α) *[mas/yr]* d)	+22.5 ± 1.5	
μ(δ) *[mas/yr]* d)	-27.2 ± 1.6	
Spectral Type	B9V e); A0V f)	
Trigonometric Parallax, π[mas] d)	3.83 ± 0.72	
Distance [pc] c)	$261\ ^{+60}/_{-41}$	
Mv c)	-0.04 ± 0.41	
Reddening, Av g)	+0.35	
Radial Velocity [km/s]	+0.7 ± 1.0 h);	

a) WDS catalog (Mason, Wycoff & Hartkopf (2003)); b) 2MASS (Cutri et al. 2000); c) Hipparcos (ESA 1997); d) Tycho-2 (Hog et al. 2000) ; e) Jaschek et al. (1964), Morgan, Hiltner, & Garrison (1971); f) Kenedy. (1983), g) Neckel, Th. & Klare (1980); h) Gontcharov (2006).

Mouzou, a maximum orbital velocity of 2.1 km s^{-1} was calculated, so B is not bound to A.

Determining the nature using the total mechanical energy

In this work I used the total mechanical energy, E, to determine the nature of BU 787 AB. The mathematical process is explained in detail in Brosche, Denis-Karafisan & Sinachopoulos (1992). We cannot calculate the true value of E, but we can calculate a projected value of E (using the relative tangential velocity and the projected separation), called Eo. Eo > 0 is a sufficient condition for a pair being unbound and this condition is fulfilled if

Table 4: Data for BU 787 AB = WDS 03342+4837 double star

	Primary	Secondary
Reddening, E(B-V)	+0.11	
Reddening, Av	+0.40	
V	7.35 a)	11.9 b)
B – V a)	+0.038 ± 0.005	…
V – I a)	+0.05 ± 0.00	…

a) Hipparcos catalog (ESA 1997); b) WDS catalog (Mason, Wycoff & Hartkopf (2003));

$$\lambda = \frac{V_{\tan}}{V_{orb\_\max}} > \sqrt{2}$$

The calculated V_{orb_max} is 0.45 AU/yr and $\lambda \approx 21$. If I take into account the error in V_{tan} and I use the expression

$$\lambda' = \frac{V_{\tan} - 2\sigma}{V_{orb\_\max}}$$

then $\lambda' = 9.4$ and so BU 787 AB is not gravitationally bound.

In summary, the three tests are in agreement with the optical nature of BU 787 AB. So this pair must be flagged with the "U" code ("*Proper motion or other techniques indicate that this pair is non-physical.*") in the Note column of the WDS Index Catalog.

Acknowledgements

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